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MARCH 1937

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Metal Progress

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Ernest E. Thum, Editor

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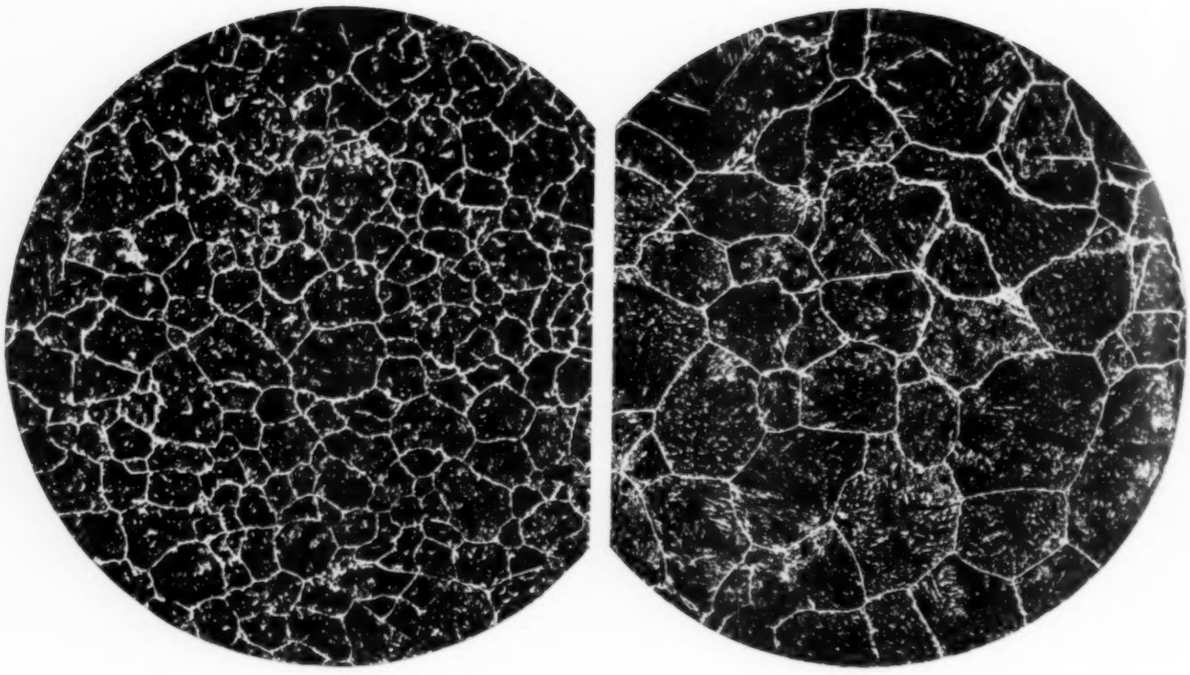

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Steels used in Ford

By J. L. McCLOUD

FORD Motor Company has for some time enjoyed the advantages of purchasing a wide variety of steels and these in large quantities. These two facts have enabled it to evolve types best suited to the needs of the various designs. It is the practice before any design or detail is released from the engineering department for the designers to confer with the metallurgical department as to the proper material and treatment to be used. By close cooperation between these departments improvements both in design and in treating methods are quickly made and taken advantage of. We could easily design a car using only three or four steels, but it would not be as efficient as our present practice of using around 40.

While in general our steels are similar to well-known S.A.E. specifications they are in most instances distinctive, as the chart on page 83 will show. It is noted at once that the carbon ranges are unusually narrow and the phosphorous and sulphur limits are unusually low. However, the steels are largely arranged so that the outside edges of any predetermined chemical range overlap, giving a valuable safety margin for the steel makers. Such selection is only possible through close cooperation between producer and user. In this we have been fortunate, and we feel that only by actually knowing the exact uses and processes maintained can the producer give the best material he in reality desires to give.

Classification of heats to five points in carbon (as well as the rest of the analysis) is done at the mill from heat samples. Even this five-point range is sometimes divided into high and low. While some spread may be found in analyses of individual bars, we have been able to maintain remarkably close limits in physical properties in our heat treated parts. In this way we have been able to establish the second general characteristic of our steels, namely, high physical properties in the completed parts.

Naturally the problem of stock keeping with so many types is no light one. A usual custom is to paint the ends of steel bars in stock in distinctive colors and figures. This practice is followed, but an additional precaution is to roll each type of steel in a distinctive section and size. This is in general taken care of by a division of the Ford purchasing department, with the cooperation of the various forge shops and departments affected.

Carburized driving pinions and gear parts are made of Type A, a chromium-vanadium steel; lower carbons in the range go into parts for Model A Ford, and high carbons into Model AA Ford trucks and Lincoln cars.

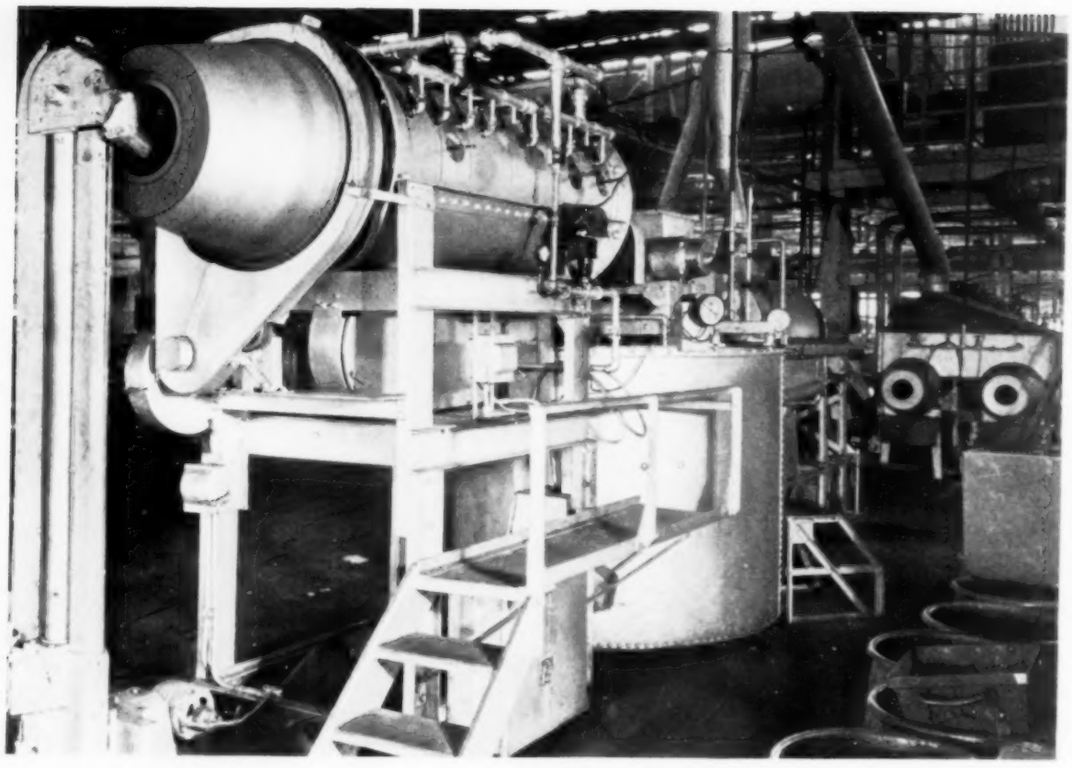
Heat treatment differs from the usual. We use only one quenching heat, and that one quite high — namely 1650° F.

Forgings for pinions are normalized. The parts are machined and then copper plated to control the location of the case. They are again machined to remove the copper where hardness is desired. After carburizing the parts are cooled in the boxes. Reheating is done in molten salt, the bath carrying a sufficient amount of cyanide to insure a clean hard surface. Quenching is in light oil (70 to 90 Saybolt viscosity at 100°) maintained at a definite temperature. Pinions are then drawn in oil at 400° F.

While we maintain a definite hardness of C58 to 65 Rockwell on the case of the pinions, we are most careful that the hardness of the core be maintained at 250 to 340 Brinell. This corresponds to a core strength of about 150,000 lb. per sq.in.

Gears are Single Quenched

Recommended practice of the A.S.S.T. for carburized gears is a double quench, the first from about 1600° followed by a low temperature quench from about 1450° F. There is no doubt that this obtains a fine grained case and core. But if we inquire into what happens in this double quench we realize that while the first operation refines and hardens the core, the sec-



Above Is a Battery of Automatic Furnaces for Ball Bearing Parts. On page opposite is a series of salt baths for hardening carburized gears and pinions

ond (while hardening the case) is an excellent annealing heat for maximum softness, and least strength, in the core. We have found, and this has been verified at the Bureau of Standards, that the wear resistance of the high carbon case is about as good even in the somewhat coarser condition secured by a single quench as in the fine grained state secured by the A.S.S.T. recommended method.

The alternate recommended method by the A.S.S.T. is a single quench from the same low temperature used as a second quench in the above method. As far as gear strength is concerned, this gives even lower values, due to the coarse, soft core.

Summing up, we find that our single-quenched gears give us far greater strength and equal wear compared with the more usual practice. These findings have been confirmed by extensive tests made both in the laboratory and in actual service.

Lincoln and AA ring gears are also made of Type A steel. The treatment in general is the same. At present some ring gears for trucks are being made of chromium-molybdenum steel, S.A.E. 4615. Perhaps less distortion is maintained but at the expense of machinability. This difference in machinability may, however, be due to the grain size inherent to the two steels; perhaps if larger grain size could be obtained in the 4615 both benefits might be reaped. Of this, as yet, we know too little.

An interesting test method was evolved for the short taper-bored pinions used in the Model T Ford. A taper pin, used as a piercing tool, was forced into the pinion and an autographic record made of the force necessary and the amount of deformation obtained in the pinion. The curves show a hook at the upper end. This test was used as a regular production check, a number of parts being tested each shift. The shape of the "hook" is regarded as being as important as the strength.

Type AX steel differs from the above in that it is straight chromium. It is, in conse-

quence, made somewhat higher in chromium and manganese. This is used very largely for carburized jigs and fixtures in tools throughout the plants and for Model A steering worms. These are normalized, machined, heated in a rich cyanide bath long enough to obtain a case at least 0.010 in. deep, and quenched in oil. Being alloyed with chromium and manganese, the core hardness is well over 300, giving exceptional strength and toughness. Since these may be oil quenched the distortion is also kept to a minimum.

Much Chromium Steel Used

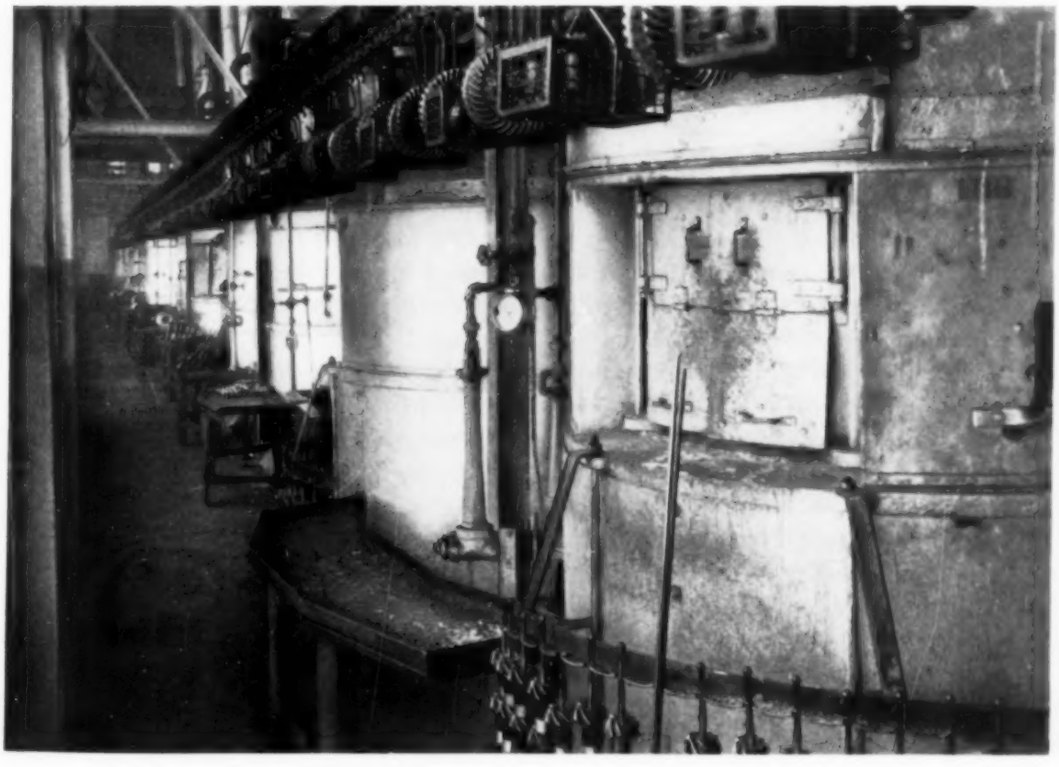
Type AA steel is the first of a continuous group of chromium steels running from 25 to 52 carbon, and differing little in manganese and chromium. Steering spindles and connecting rods are now the most important use of it.

Model A connecting rods are hardened in electrically heated conveyor furnaces with automatic quenching. Temperature of the quenching water is controlled as well as the length of time in the quench. We have noted that time in the quench is the most important item in controlling quenching cracks and specify that connecting rods (and other parts as well) must be removed while still quite hot. Drawing is done in a similar furnace. These parts are left at quite a high level of hardness: 286 to 321 Brinell. This means that machining is not simple — but machinability is a matter of desire and our machine shops have been taught to handle steels of such hardness.

A further complication is in the design. These rods have integral studs, instead of using the conventional bolts. These studs must be of sufficient hardness to insure proper strength (Brinell 286) yet not over 321, so as not to be brittle.

A great quantity of this AA steel has been successfully cold headed to form Model T connecting rod bolts. It has a minimum elastic limit of 100,000 lb. per sq.in. and a reduction of area of more than 60%. It was quenched and tempered prior to cold drawing.

It is also used, heat treated and cold drawn in hexagonal section for the highest strength nuts, as for Lincoln connecting rod bolts. We



also select certain heats on the high side for highly stressed and vital parts, such as steering spindles for Model A.

Type AAAH steel was evolved for gears in the Model A transmission, requiring somewhat higher hardness than the lighter Model T gears. After normalizing and machining the gears are heated in molten salt bath furnaces, oil quenched and oil drawn at 400° F. A hardness of C50 to 55 is maintained.

Transmission shafts are also of this same material. For these the steel is purchased cold drawn of a hardness of 170 to 228 Brinell.

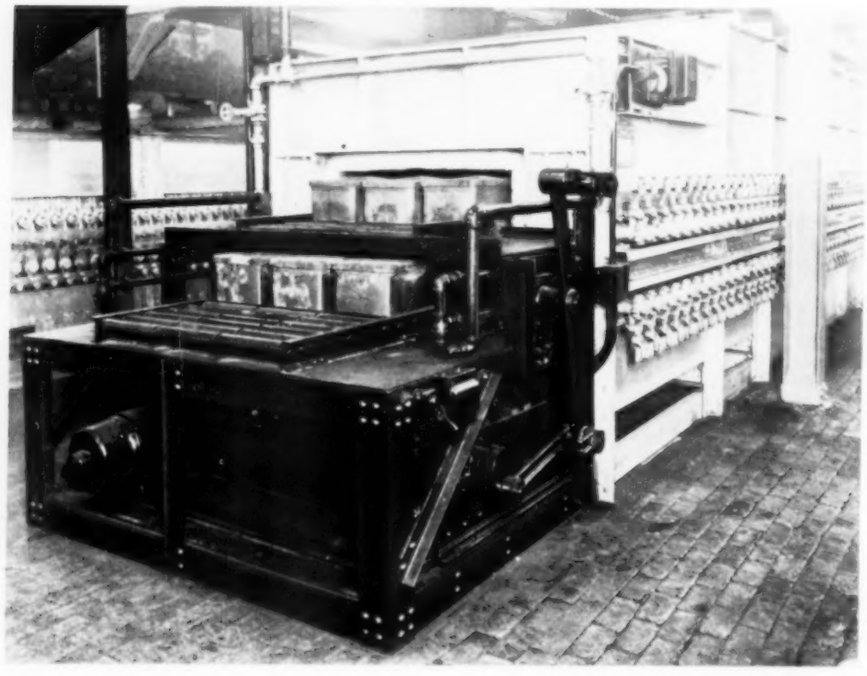
In the choice of gear steel analysis we again do not follow the usual practice of about 0.45 to 0.50% carbon. We have found that heating a lower carbon steel in a molten salt bath containing cyanides will give a clean, file-hard surface. We also know that better tooth strength and wear are obtained after a low draw (400° F.). This strength is measured by impact resistance and slow loading tests.

The steering worm sector of AAAH steel is representative of a class of parts that are differentially heat treated so that different hardnesses are obtained in the same piece. Forgings are normalized, machined and hardened in oil from a cyanide salt bath. They are drawn in molten nitrate at 800° F. to a Rockwell of C38 to 45 on the shaft end only. In this way the gear teeth are left at C53 to 58.

The next series of steels noted on page 81 are all used in ball bearing work.

The B steel is used for balls up to ½-in. size. These are cold headed of soft wire and hardened in water. BB steel is used for larger balls, also water hardened. BBB steel, for bearing races, is quenched in oil; the hardness maintained is C61 to 68.

In order to show that we have a definite chemical analysis set for ordinary screw stock, we have put up a little red flag, "No. 1" and this does give the intended results. It is used in general for machined parts made of cold drawn bars where stresses are not high and clean finishes are important. Nuts and some bolts form its greatest bulk. It is also used for a few parts that are later hardened either by carburizing and hardening or by cyanide hardening with water quenching. If this hardening is done at sufficiently high heat, 1560° F., a good degree of toughness is obtained.



Counterflow Furnaces for Carburizing Pinions and Gear Parts. Both hearths are close - nested rollers; all are turned simultaneously by ratchets attached to walking beam

Medium Manganese Steels for Forgings

Steels in Class E differ mainly in carbon content, although the first is held down to 0.03% phosphorus. They are widely used. While sometimes classed as carbon steels they have somewhat higher manganese than ordinarily found in these carbon ranges and are akin to those recently described in technical literature as "medium manganese steels." Automotive builders can take credit for pioneering in the use of these steels in America. Today very large tonnages are absorbed by large bridges and other structures.

They are used for various parts and in various physicals; ranging from thin flat strips, hard rolled to a mild spring temper, to large forgings (crankshafts and truck hub and rear axles), and to cold drawn rods used either in the treated or untreated condition.

An enormous amount of type E steel has been successfully headed into screws and bolts. Such a bolt can be produced with quite high physicals and threads can be rolled or cut. We also head some EE (the 0.35 to 0.40% carbon range) into valve push rods; the headed rods are hardened in a continuous electric furnace and quenched in a caustic soda solution to a hardness of C50 to 55. (It might be well to emphasize the value of this quenching solution. Until H. J. French of the Bureau of Standards described its properties it was little known outside of Ford Motor Co. We use a 7% solution, equivalent to 10° Baume. It has four important properties — it throws scale off remarkably, it hardens evenly and deeply, quenching speed is little affected by quenching temperature, and the work so quenched is not as readily inclined to rust.)

In the cold drawn state all three of these steels are used for pins, studs, and for highly important nuts. In general they all machine well, giving smooth finishes — a factor often as important in some parts as high strength is in others.

These steels also have good hardening capacity either in oil, water or caustic brine. All these quenches are used, depending on the sections encountered, on the intricacy or liability to warp and on the hardness or physical properties desired. We do not find that brittleness commonly believed to be associated with high manganese.

All three types in this class are used in forgings, sometimes as forged, sometimes normalized, sometimes treated to medium hardness (about 250 Brinell), sometimes hardened to capacity (500 Brinell). For instance, universal joint housing caps are E steel as forged, the spare wheel carrier support is EE steel also left as forged. The hardness of the former runs from 137 to 196, the latter from 149 to 196. Brake pedals of E steel are heat treated to 228 to 286 Brinell. Emergency brake toggle levers of EE are heat treated to 228 to 269.

Spring perches for Model A are made of EE steel and treated to 286 to 321 Brinell before machining; after machining, the shock absorber ball (a part of this same forging) is rehardened to C45 to 50 in a cyanide salt bath. The surface is maintained file hard.

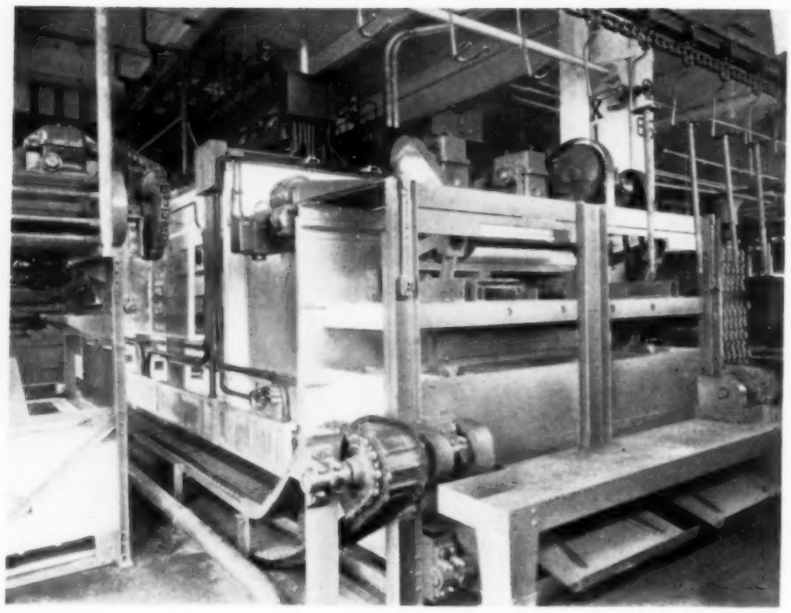
While these steels have good hardening capacity the very fact that they do not harden as deeply as chromium steels has made them preeminently valuable for many parts.

Improved Crankshaft

It is, of course, a most valuable asset to have a hard bearing on crankshafts and yet they must have high fatigue value. Our experience has shown that a crankshaft, such for instance as was used in Model T motors, if made of EE steel and finished with a Brinell of 402 to 444 had a fatigue life of 5 to 20 times that of a chromium or chrome-nickel steel at its optimum fatigue hardness (about 321 Brinell). This same experience has enabled us to make a crank of the same high hardness for the Model A engine. In the design of the Model A crankshaft, however, so much higher rigidity has been obtained that the fatigue value is not so important a consideration.

The method used to determine this fatigue value in a crankshaft is as follows: A finished crankshaft is assembled in a motor having a center main bearing purposely $\frac{1}{8}$ in. out of line. The motor is then run under its own power until the crankshaft breaks.

A shaft of AA steel, heat treated to 286 to 321 Brinell, runs from 4 to 12 hr. at 1000 r.p.m. Some shafts of chrome-nickel-molybdenum



Drawing Machine. Each part moves through furnace while held in a fixture that prevents contact with neighbors but which uses furnace space economically

steel made in England and heat treated to the same hardness, ran 6 to 8 hr. Shafts of EE steel, hardened on the bearings to 402 to 444, always ran more than 18 hr. Runs of 100 hr. were usual, and one test was without failure at 1000 hr.

Such a shaft has a very hard surface and a uniformly graded backing to about 228 Brinell at the center. We believe that the explanation of such remarkable results is in this graded hardness, and work of Prof. H. F. Moore at the University of Illinois with carburized test pieces confirms our results.

When properly surface finished this type of crankshaft, due to its hard surface, does not "drag" babbitt and can be operated at high speeds without danger of damaging the engine even when "running in."

Special quenching machines, directing caustic sprays against the parts required to have highest hardness, have had much to do with the development of uses for these medium manganese steels. Cam shafts of EE steels are produced with cams and bearings C55 hard. Model A rear axles are somewhat softer, but in this part three separate hardnesses are maintained: C50 to 55 on the gear (forged integral with the shaft), Brinell 402 to 444 from the gear to taper end, and 302 to 340 at the taper end to carry the torsional stresses imposed on the hub key thus giving wear, rigidity and toughness.

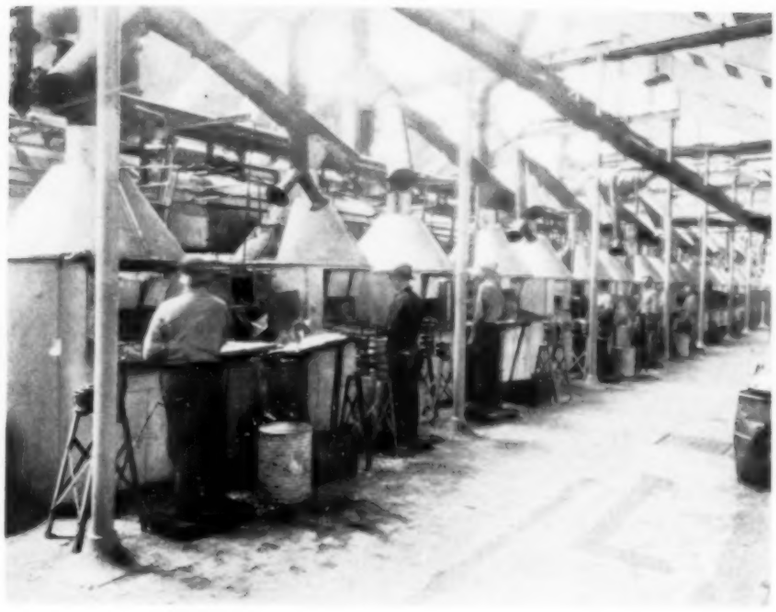
In truck axles EEE steel is used in somewhat larger sections, but with properties identical with those obtained with EE.

As an oil hardening steel EE is used for speedometer driving gears. Good surface hardness is obtained from a cyanide salt bath and (in this section) good core hardness with little distortion.

Probably no other class of steels finds a wider variety of uses in the Ford Industries than these E steels.

Type GG steel is used for forgings, largely where these are not machined afterwards and where the stresses are not high. It also is used where relatively low carbon is desired, but where machinability is also important. It carries enough carbon, and consequent hardness, so that there is little danger from tearing. This makes it useful for parts produced on an automatic screw machine which are to be later hardened from a cyanide salt bath. With a water quench from 1560° such small parts will have a file-hard surface with a core of about 300 Brinell and very good toughness.

Steel of Type H was originally mostly used for sheet parts, either hardened in oil if thin or water if heavy, but now is more useful for forg-



Battery of Cyanide Baths and Oil Quenching Fixtures for Clutch Plates Used by Fordson Tractors. Tolerance is "flat to 0.001 in."

ings that are to be butt welded electrically. Carrying 0.27 to 0.37% carbon it machines nicely. With its lower manganese (0.45 to 0.60%) the flash produced does not harden and is more easily removed. It is consequently used for Model A steering gear housings.

This is the steel used in multiple discs, oil-immersed clutches, Model T and Fordson. For this purpose it was heated in a cyanide bath and quenched in oil while being held rigidly between jaws of special machine. Such thin sections hardened to C35 to 50 and are maintained flat to 0.001 in.

A large tonnage of low carbon open-hearth steel goes into body, fenders, hoods and miscellaneous small parts. It is used in a variety of tempers, hot or cold rolled. We buy sheets and strips with physical properties guaranteed to form the part rather than specify any drawing tempers.

W. H. Graves, Jr., of Packard Motor Co. at the Detroit meeting of the American Society for Testing Materials, April 1930, stated in a paper on "Automotive Sheet Steel" that metallurgical practice in testing had advanced to a higher state of perfection than die design and stamping practice. This may be true, but we are still buying steels specified to form certain parts and in general leave it to the sheet mill metallurgists to supply what is needed. This, of course, makes it necessary for the Purchasing Department to keep the mills competitive in what they will offer.

Type N steel is a low alloy which we use for carburized parts. It hardens uniformly but without as high core strength as Type A. At present its only use is in piston pins.

Alloy Steels for Fatigue Resistance

Another interesting use has been as staybolts for the Detroit, Toledo & Ironton locomotives. Fatigue limit of wrought ferrous metals is proportional to the ultimate strength, and when staybolts function in such a way that fatigue is a most important factor, they have been almost exclusively made of wrought iron, but with heat treated N steel we can obtain twice the ultimate and elastic limit of wrought iron and with equal elongation and better reduction of area.

Another point that must be considered in staybolts is the ability to peen or rivet the ends. We have installations of these where the acetylene flame is used for cutting. As this is a low carbon steel it does not harden to any extent. All these points were considered before selecting this steel for staybolts, and the service rendered in the past several years has proven the correctness of this reasoning.

Welded Steel Drums

. . . for scout cruisers

BY J. C. HODGE

DEVELOPMENT of welded joints suitable for heavy welded pressure vessels, the present widely extended use of welded pressure vessels in the oil and chemical industries, and the still greater potential use of welded pressure vessels for the boiler industry, elevates any proposed specification for fusion welded pressure vessels to a place of great importance and interest.

If 100% efficiency is to be granted, it is immediately apparent that the joints must be at least equal in quality to the plate or base material from which the vessels are constructed. They should be free from gross defects such as cracks, porosity, slag inclusions, incomplete fusion, and should possess strength, ductility, resistance to failure by the application of sudden stresses and resistance to repeated applications of stress to the same degree as the base metal. The effect of corrosion fatigue further complicates the problem.

And yet an examination of some of the specifications for welded pressure vessels of the oil industry, the present largest users of welded vessels, would reveal that three or four pages are devoted to the requirements of the plate material while the requirements for the welded joints are massed together in three or four lines, usually confined to the statement that the tensile strength of the weld shall be not less than that of the plate!

There are two general methods of writing a code or specification governing the quality of welded joints in pressure vessels: One involves a procedure control — the setting down of rules governing innumerable details of the welding process such as type of joint, current density, and acceptance tests of operators. While this method may cover certain fields of work, it can not be relied on to obtain the very best type of welding. An analogy would be a specification for plates, based on control of the steel making process, involving instructions as to additions of pig iron, ore, fluxing materials, ferro-alloys and so on.

The second method of specification involves a testing procedure on the finished vessel. This method is the more logical one. We should not be so much concerned with how the welds are made as we should be interested in the quality of the joints produced by any process or technique.

In a paper presented by the writer before the American Welding Society, September 1930, the following was offered as a fundamental basis of specifications which would guarantee satisfactory performance under severe operating conditions:

1. The securing of welded test plates, which are obtained under conditions as near as possible to the conditions under which the main welded joints in the pressure vessel are produced. The determination of the tensile properties, the ductility under bending, the impact values, the macro and microstructural characteristics and the chemical analysis of the weld metal on specimens obtained from the above test

Abstract of Paper for Western Metal Congress

plates. These properties must comply with the values of a rigid, yet reasonable, specification which will guarantee a high quality of weld metal.

2. The exploration of the main longitudinal and circumferential welded joints of the finished welded drums by an approved non-destructive test which would determine quantitatively the size and location of a defect within the welded joint.

3. The subjection of the completely welded drum or pressure vessel to a hydrostatic test pressure of some value considerably higher than the working pressure of the drum or vessel.

In March, 1930, the Boiler Code Committee of the Mechanical Engineers "Proposed Specifications for Fusion Welding of Drums or Shells of Power Boilers," which were based on these fundamentals. Requirements are tabulated on page 42. In December, 1930, it also "Proposed Specifications for Fusion Welding on Unfired Pressure Vessels," based on the earlier specifications proposed for power boilers.

The first official recognition of these proposed specifications of the Boiler Code Committee came with the adoption by the U.S. Navy of arc-welded construction for the joints of drums for 24 boilers now being built by the Babcock & Wilcox Co. for the new scout cruisers Minneapolis, New Orleans, and Astoria. The specifications governing the construction of these first fusion welded boiler drums were based on the original Boiler Code Committee specifications, as revised and amplified by the Bureau of Engineering, U.S. Navy. Principal requirements are also shown in the tabulation at the top of the next page.

We shall now proceed to examine the workings of such a specification, taking for example, the first of the welded boiler drums for the Navy.

Welded Test Plates. Representative welded plates for test pieces are obtained by tack-welding sample plates at the ends of the seam. Weld metal is deposited in the test plates at the same time and under the same conditions as the corresponding longitudinal seam of the drum shell, as shown in the figure on page 41. The joint is of the single vee type.

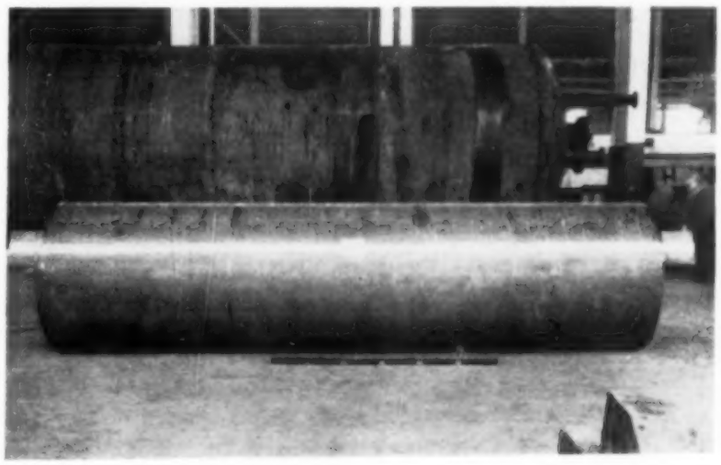
Tension Tests. Two types of tension specimens are obtained, one to represent the joint (designated as a "transverse tension test specimen"), and the other to represent weld metal only (designated as a "longitudinal all-weld metal specimen").

For the transverse tension specimen it is specified that on testing failure should occur in the boiler plate. If failure occurs in the weld metal or along the line of fusion, then the tensile strength shall not be less than the mean of the specified tensile range of the boiler plate used.

Tensile strength of the longitudinal all-weld-metal tension test must be equal to the mean of the tensile range of the plate, 65,000 lb. per sq.in., and have 20% minimum elongation in 2 in.

The actual value of the specimen from the first Navy drum was:

Ultimate strength	66,500 lb. per sq.in.
Yield point	45,750 lb. per sq.in.
Proportional limit	30,000 lb. per sq.in.
Reduction of area	64.7%
Elongation in 2 in.	36.8%



First Boiler Drum for Navy Scout Cruisers After Longitudinal Seam Had Been Welded. Note plates at each end which have been welded as a part of the seam and from which test specimens are to be cut

Bend Tests. For determining the ductility the bend specimen is transverse to the welded joint, of the full thickness of the plate, and of rectangular cross-section with width 1½ times the thickness of the plate. Ductility is expressed as the per cent elongation of the outside fibers of weld metal during bending. The specimen must bend cold under free bending conditions, until the least elongation measured on the outside fibers is 30%. A photograph of the specimen from the first Navy drum test plate is shown on page 43. The plate is 1 in. thick; it bent 190° to a radius of 0.40 in. and the elongation is 52% in 1 in.

A similar test in 5-in. plate broke in the plate when the elongation of the outside fibers of the weld metal had reached 30%. This statement is merely included to show that a satisfactory bend test could be made on a welded joint in a plate of this great thickness.

Impact Tests. Three specimens are removed in such a manner that the impact resistance of the metal is obtained for the bottom, middle and top of the welded joint. These specimens must show an impact value of at least 20 ft-lb. in 0.394-in. square Charpy impact specimens with keyhole notch. (National Metals Handbook, p. 447.)

Macro and Microscopic Examination. It is specified by the U.S. Navy that a section across the weld is to be polished and suitably etched and on macroscopic examination is to be free from evidence of incomplete fusion, laps, cracks, blowholes greater than ⅛ in. in any dimension, and slag inclusions greater than 1/16 in. in any dimension, and of excessive porosity. The ratio of coarse-grained material to fine-grained material in the weld metal, as shown on page 44, must not be greater than 1 to 5.

COMPARISON OF SPECIFICATIONS FOR WELDED PRESSURE VESSELS

	Plate or Base Material	A.S.M.E. Boiler Code			U.S. Navy Specifications	Properties of Babcock & Wilcox Welded Joints
		Welded Pressure Vessels	March 1930 Proposed for Welded Joints in Power Boilers	Dec. 1930 Proposed for Welded Joints in Unfired Pressure Vessels	Joints in Power Boilers for Class B Marine Plate	
Ultimate strength lb. per sq. in.	55,000 to 65,000	90 to 100% of min. of tensile range of plate	55,000 min.	55,000 min.	52,000 min.	65,000 to 74,000
Yield point lb. per sq. in.	0.5 tensile strength	Omitted	Omitted	Omitted	Omitted	47,000 to 52,000
Elongation	25% in 8 in.	Omitted	Omitted	20% in 2 in.	20% in 2 in.	20.5 to 38.0%
Bend test	180° around pin 1/4 to 3 times the thickness	Omitted	30% elong. of outside fibers	30% elong. of outside fibers	50% elong. of outside fibers	50% elong. of outside fibers
Impact tests	Omitted	Omitted	20 ft.-lb.	20 ft.-lb.	20 ft.-lb.	28 ft.-lb.
Homogeneity test	Required	Omitted	Omitted	Omitted	Omitted	Omitted
Macro examination	Corresponds to homogeneity test	Omitted	Required	Omitted	Required	
Micro examination	Omitted	Omitted	Required	Omitted	Required	
Specific gravity	Omitted (will be about 7.85)	Omitted	Omitted	7.80 min.	7.80 min.	7.82 to 7.83
Chemical analysis		Omitted		Omitted		
Carbon	0.25 max.					0.08 to 0.15
Manganese	0.30 to 0.50		0.30 to 0.60		0.30 to 0.60	0.30 to 0.60
Sulphur	0.04 max.		0.045 max.		0.045 max.	0.045 max.
Phosphorus	0.04 max.		0.04 max.		0.04 max.	0.04 max.
Nitrogen as iron nitride	Omitted (will not usually be over 0.009%)		0.02 max.		0.02 max.	0.02 max.
X-ray examination	Omitted	Omitted	"Non destructive" test required	Required	Required	

It is also specified that photomicrographs shall be made showing typical structures of plate, zone between weld metal proper and plate, the line of fusion, and the structure of the weld metal.

Specific Gravity Determinations. To guard against an excessive amount of porosity, specific gravity determinations of the weld metal are made on two all-weld-metal specimens and these shall show a minimum value of 7.80. Solid rolled plate of 0.20 to 0.30% carbon possesses a specific gravity of 7.85.

Chemical Analysis. A considerable amount of opposition to the inclusion of chemical requirements of the weld metal has been manifest, yet it is apparent that a welding is in reality a steel making process. A chemical analysis of the steel produced is therefore in order. The *value* of a chemical analysis when the physical properties of the steel are also specified, is a rather debatable question, but in specifying the chemical analysis for the weld metal, welding specifications would only follow present accepted practice in specifying steels.

The effect of nitrogen on weld metal has not been well established, but all investigations point to the fact that a high nitrogen content in steel reduces its ductility. If a high nitrogen

content were common in our steels produced under present steel making processes, a limit would certainly be placed in every steel specification. With welding processes we have conditions under which there is every possibility for a high nitrogen content being present in the finished metal. Just what the maximum value for the limiting nitrogen content should be may be open to debate, but we feel that it should be kept as low as possible.

It is admitted that the presence of oxides in the deposited metal is vastly more significant than the presence of nitrogen. Yet apart from the difficulty of making accurate oxygen determinations by chemical analysis, the true significance of the value obtained is rather difficult to interpret. Oxides present as harmful oxides will vary depending upon the particular welding process; however, a low nitrogen content in the weld metal indicates good protection of the weld metal during deposition. A low FeO content is often shown by a low nitrogen content.

As an extremely practical effect of the importance of chemical analysis, the following data are presented to indicate that the resistance of weld metal to corrosion is closely related to its oxide and nitrogen content. (It is a well-known fact that the resistance to corrosion of weld metal deposited from ordinary bare electrodes is very much inferior to that of rolled and forged low-carbon steels.) An experimental welded joint in 5-in. plate was pickled in hot hydrochloric acid (1 to 1). Certain areas, most readily attacked by this treatment, were eaten out $\frac{1}{16}$ in. below portions which have been but slightly affected. This remarkable difference in the rate of corrosion was investigated by chemical analysis and micro examination.

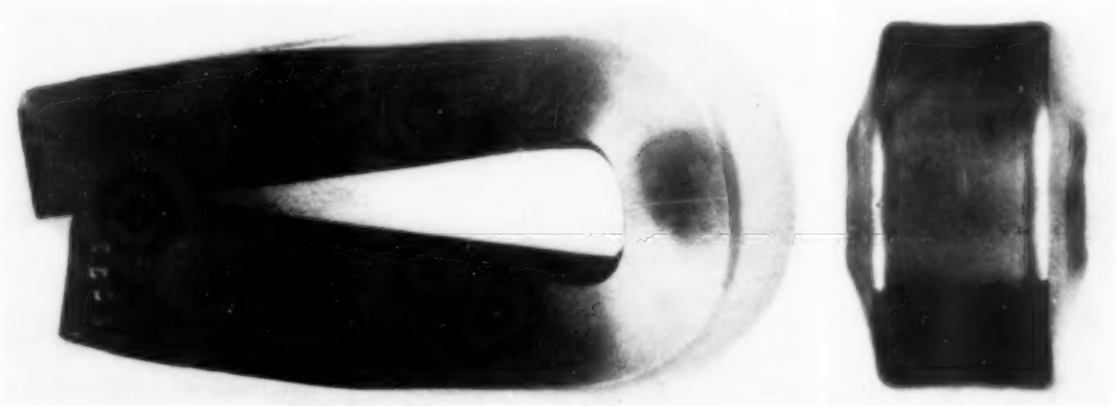
Drillings were taken from the more soluble weld metal at positions C-1 and C-3, from the less soluble weld metal at C-2 and C-4, and from the base material. Chemical analyses are given below, wherein "residue" is weighed after SiO_2 volatilization:

	C-1	C-2	C-3	C-4	Plate
Corrosion	High	Low	High	Low	Midway
Carbon	0.056%	0.076%	0.070%	0.096%	0.182%
Manganese	0.20	0.32	0.23	0.33	0.67
Silicon	0.06	0.08	0.07	0.05	0.009
Residue	0.035	0.001	0.030	0.001	0.005
Nitrogen	0.046	0.035	0.052	0.039	0.008

Nitrogen in the readily corroded weld metal is over 30% higher than in the less corroded portion. This indicates that it is at least a contributory cause. This, coupled with the oftentimes observed fact that a HCl solution of weld metal contains more insoluble residue in samples subsequently proven to be high in nitrogen, leads to the belief that the comparatively easily determined nitrogen content gives an indication of the degree of detrimental oxidation of the weld during deposition.

Except for the appearance of nitride needles in the highly corroded zones, and the absence of nitride needles in the less corroded zones, no

Welded 1-Inch Plate Bent Under Press Without Fracture. Angle of bend is 190°; inside radius of bend is 0.4 in., and elongation of outside fibers across weld is 52%



difference in the microstructure exists between the two zones. Although the average nitrogen content of the less corroded weld metal is 0.037%, no nitride needles are apparent. Evidently it is necessary to have 0.040 to 0.045% before the characteristic needles can be seen after the weld metal has been subjected to a stress-relieving treatment at 1200° F.

Correlating the macro, micro and chemical examination of this weld (conditions which have been repeatedly verified), it is shown that the weld metal which is more readily attacked by hydrochloric acid shows the following characteristics:

1. Microscope reveals nitride needles
2. Nitrogen is higher by 30% or more
3. Less carbon, manganese and silicon
4. Insoluble residue, remaining after volatilizing the silica in the silicon determination, is higher.

All of the above conditions indicate that the deeply etched sections of the weld metal were deposited under less favorable conditions than the sections showing less corrosion, and that excessive atmospheric contamination occurred.

I have dwelt at some length on the chemical analysis of the weld metal, not because of its greater importance than the physical requirements, but because of the tendency to underestimate its importance.

Non-destructive Test. In the past it has been repeatedly stated that the development of a suitable non-destructive test for the examination of welded joints in the finished welded pressure vessel would dispel all doubts in the minds of engineers regarding the satisfactory performance of welded vessels. A suitable technique has been developed, and all of the proposed specifications shown in the table include X-ray examination of welded seams. This method of non-destructive testing is able to determine quantitatively the size of a defect when its thickness is greater than 2% of the thickness of the plate.

Radiographic prints of the joint under study are compared with a set of standard radiographs, selected to show varying degrees of weld metal qualities. Both the specifications of the U.S. Navy and the specifications for the fusion welding of unfired pressure vessels proposed by the Code Committee in Dec. 1930, use the five radiographic prints reproduced on page 45 as standards for comparison.

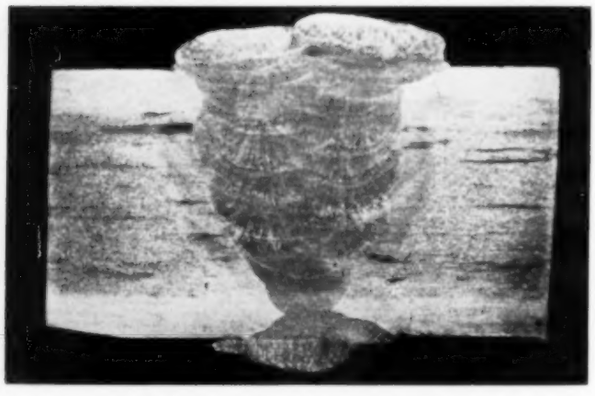
While porosity is readily indicated in a radiograph, the *degree* of porosity is more readily controlled by the specific gravity determinations, which express porosity numerically.

The most important function of X-ray determination is the detection of defects of type No. 4, consisting of slag inclusions or cavities extending longitudinally along the walls of the joint and being of a very dangerous type. No. 5 is used to illustrate the presence of an isolated defect of this type, which under the specification is limited ⅓ the thickness of the plate, and which must be more than twice the thickness of the plate from any other defect of this type.

Typical radiographs of the longitudinal seam of the first welded boiler drum for the U.S. Navy correspond to Type 1.

Stress Relieving at 1200° F. is required by the specification, and the need for its inclusion is obvious.

Hydrostatic Test. Although not specified because of its destructive nature, a severe hydrostatic test was given a welded drum, built according to the specifications adopted by the Bureau of



Relative Area of Coarse-Grained and Fine-Grained Zones in Weld Metal Is Held to a Minimum. At 100 diameters the coarse-grained area has a columnar structure, whereas the fine-grained has recrystallized into equi-axed particles

Engineers, U.S. Navy. It was 47 in. outside diameter, and 14 ft. long overall, made of 1-in. plate. It possessed one longitudinal welded seam and two circumferential welded seams attaching the heads to the shell. All excess weld metal had been chipped and ground off flush with the plates. During the hydrostatic test the drum was subjected 14 times to a pressure of 2,830 lb. per sq.in., the pressure in each case being raised from zero. The drum did not rupture under these large over loads, although it expanded in circumference from 148 in. to 162 in.

Based on a factor of safety of five and considering that the plate material had an ultimate tensile strength of 55,000 lb. per sq.in., the formulas of the A.S.M.E. boiler code show that the working pressure of the shell is 489 lb. per sq.in., and the working pressure of the manhead is 487 lb. per sq.in. Assuming that the yield point of the plate material was 33,000 lb. per sq.in. the pressure at which the yield point of the shell was reached was 1,021 lb. per sq.in. The above maximum test pressure of 2,830 lb. per sq.in. corresponds to a maximum hoop stress in the shell of 63,450 lb. per sq.in., based on the original diameter of the shell, or 69,864 lb. per sq.in. figured on its final diameter.

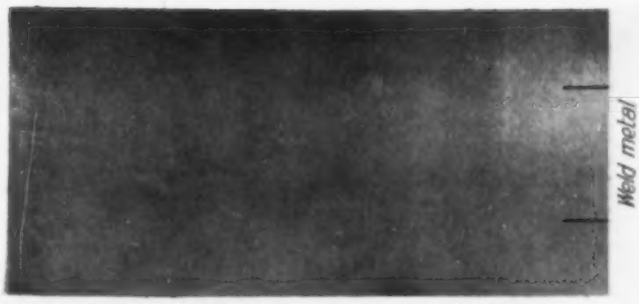
Conclusions. This paper has indicated the present tendency toward specifications, based not upon control of the welding process but upon testing the welded product. Testing procedure is based upon three fundamentals:

1. Determination of the physical and chemical properties of representative sample welds

2. Non-destructive examination of the welded seams by X-ray

3. Hydrostatic testing of the finished welded vessels.

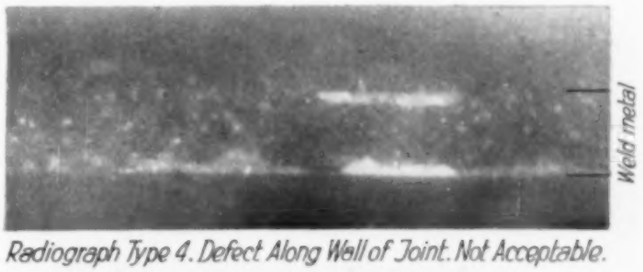
The nature of these specifications indicates that the quality is no longer dependent upon the skill of individual operators and numerous other variables, but may be proven by scientific tests, which leave no doubt as to the successful performance of the vessel.



Radiograph Type 1. Excellent or Ideal Weld.

Radiograph Type 2. Porous but Acceptable.

Radiograph Type 3. Porous and Not Acceptable.



Radiograph Type 4. Defect Along Wall of Joint. Not Acceptable.

Radiograph Type 5. Defect Along Wall of Joint. Acceptable if length of defect is less than ½ thickness of plate and is distant more than twice thickness of plate from another.

Photo by Brenza Studios for Cleveland Worm & Gear Co.

Brown-Lipe-Chapin's

Gear Testing Fixtures

BY FRED C. RAAB

INTERPRETATION of the standardized tensile and hardness tests on steels and alloys becomes increasingly difficult as the machine parts for which the metal is intended increase in complexity. The conventional tests mentioned are invaluable to verify the uniform quality of the raw material, and our inspection tests were described at length in an article in METAL PROGRESS last December. But it does not follow, for instance, that one steel will make a better gear than another steel because the newly proposed one has a higher ultimate strength or elastic limit in the condition as received from the mill.

Consequently, metallurgists in the automotive industry have given much thought to specialized tests which would indicate more nearly the comparative excellence of steels and of variations in heat treatment of a single steel — tests which have a close relationship to the actual duty in the part. For instance, a pinion or gear tooth in an automobile differential must resist a combination of wear, repeated impact, static crushing and bending. What test or tests can be devised to indicate excellence of material for such duty, short of putting the gears into a car and running it 50,000 miles? Stresses in a crankshaft, running at high speed, are impossible to compute exactly. How can the engineer be sure that the design is not too highly refined?

Even though they recognized that service in a car is the only conclusive test of excellence of an automobile differential, the engineering and metallurgical departments of the Brown-Lipe and the Brown-Lipe-Chapin companies in Syracuse, N. Y., have designed some special fixtures for short-time tests on finished gears. A description of them as they are now in use by Brown-Lipe-Chapin will doubtless be suggestive to men in other manufacturing lines, who are searching for means of interpreting variations in shop practice.

For instance, the testing equipment which is about to be described has not only been used to great advantage in commercial research on the improvement of the product, but also as an additional form of routine inspection. If, for any reason, work in process becomes suspect, a few samples can be finished and put through these special tests, and if they fail to give satisfactory results, the rest of the lot can be scrapped without further waste of labor, or the

manufacturing routine so modified as to salvage them.

Most gears wear out, rather than break. Consequently, a wear test should be best. But, as is well known, this variety of test is quite difficult to conduct, and depends primarily upon whether the rubbing surfaces are properly lubricated. Furthermore, in order to get the results of duplicate tests to check within reasonable limits, the gear teeth must be cut with highest accuracy.

Hardest Gears Wear Longest

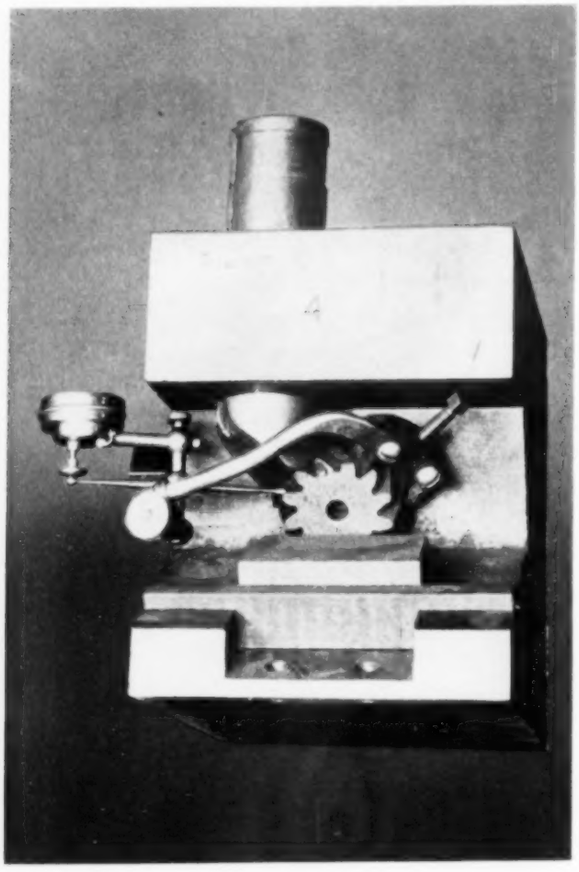
This problem of wear testing is one which is more mechanical than metallurgical, and can be passed for the time being, but it may be mentioned in passing that the prime requirement of a gear tooth is hardness, to resist wear. It has, therefore, become practically standard practice to make automobile differentials of carburized steel, heat treated file hard. If there were a ready means of comparing the relative hardness of surfaces which a sharp file cannot touch, it might be possible to progress faster with this problem of wear resistance.

In a carburized gear the condition of the core is responsible for the physical properties desired in a tooth, with the exception of wear. The core must be strong enough to hold the hard brittle wearing surface up to its work. It must be strong and stiff enough to carry the loads without undue deflection, and tough enough to absorb the impacts of engine compression and acceleration. In view of these requirements, the specialized tests for gears in use at Brown-Lipe-Chapin are designed to check up the ability of the core of a finished and hardened gear to stand up to its expected loads.

Briefly, the devices in use are fixtures whereby the gear or pinion is held rigidly in such a manner that a static load or series of impacts can be placed on a single tooth, and the resulting deflections measured.

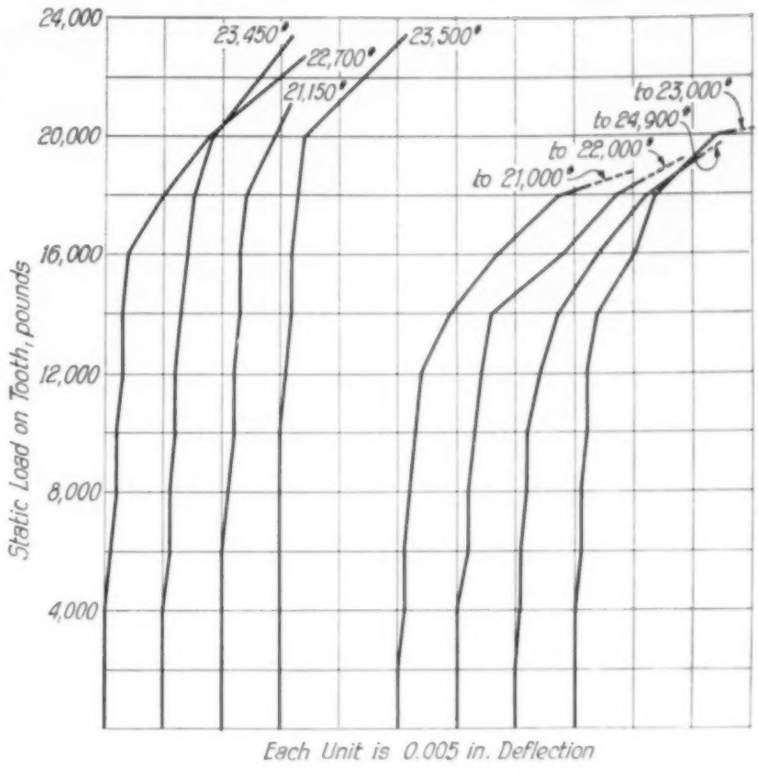
Equipment to test a pinion is a steel block with a hole drilled at proper slope and diameter for the shaft of the pinion. A complete set-up is shown in the view on this page. Heavy set screws are driven through either side of the steel block to grip the flat shanks on the gear shaft, and hold it in place. However, the main resistance to rotation of the pinion, when under test load, is offered by a section cut from a mating ring gear and bolted to the bottom shelf of the block.

Prior to mounting the pinion rigidly in this manner, one tooth is cut out, in order that the punch may rest squarely on the tooth to be tested. This punch is made of a 1.25% carbon tool steel containing 3.5% tungsten, 0.5 silicon, 0.35



A Pinion Is Fixed in a Steel Block and Prevented From Turning by Placing a Gear Segment in Mesh and Bolting to the Bottom Shelf. A load is then placed on one tooth by the round punch. Movement of the tooth is measured by lever arms and Starrett dial

Load-Deflection Diagrams Made With Fixture Shown on Opposite Page. Group at left indicates gears with stiff teeth; at right are curves which deflect and acquire permanent set at lower load. The only difference between the two groups is the hardening treatment



manganese and 0.15 chromium, heat treated to maximum hardness and drawn to Rockwell C50. It is round cross-section with a generous keyway, and operates through a slide with minimum clearance so there is no possibility of rotation while under load. The lower end is shaped very carefully to give an exact bearing on the tooth, at the desired position and of correct dimension. It is also held down by a spring, so it will not bounce away from the tooth in the impact test.

To measure deflections of the tooth the bent bar shown in the view is rigidly fixed by a species of C-clamp to a pair of teeth on the opposite side of the pinion from the tooth which is being tested. At its outer end is affixed a Starrett dial, a fulcrum and a rocker arm, the outer end of which presses against the dial mechanism and the inner end of which touches the under side of the tooth which bears the load.

Such a set-up is placed on the bed of a standard testing machine and the head run down until it comes in contact with the top of the punch. Enough load is placed on the tooth to cause it to deflect 0.001 in. (as measured on the dial). Load is then released, all bolts on the fixture tightened, the dial set to zero, and then loads placed on the tooth by increments of 2,000 lb. Each load is released in turn, and the process continued until the tooth is sheared off.

Data as shown on the curves are thus secured on the elastic properties of the tooth, regarded as a beam in bending. The extension of this curve shows the plastic deformation of the tooth up to the time of fracture. As before mentioned, the punch is very carefully made to place the load on the tooth in a band across the face of the tooth at practically the same place where it would come in a perfectly developed pair of mating gears. If this point were neglected, or if there were any play in the punch, the results of such a test would be valueless. Clearly if one tooth were loaded further from the root than another, the deflections under load would be quite different.

When loading is correctly placed, the elastic curves of the teeth of given dimension are approximately equivalent. This is because the modulus of elasticity of steel does not change materially by composition or heat treatments.

The curve of plastic deformation (that is, the curve which shows the amount of permanent set at overloads) is characteristic of the design of the tooth and the strength and toughness of the metal which it contains. Obviously a tooth which deflects little for large overload, like the left-hand curve in the figure, is superior to the other one which is more plastic.

Curves show that results are reproducible with satisfactory accuracy. All eight gears were cut on the same machine set-up and are identical in size and shape. All were carburized in production in one pot. The four with the high elastic limit were given a single treatment (a soak at 1,440° F. for 45 min.). The other four were given a double treatment. The single-treated gear will not acquire a permanent set until a tooth is loaded beyond about 18,000 lb. The double-treated gear is deformed at 14,000 lb.

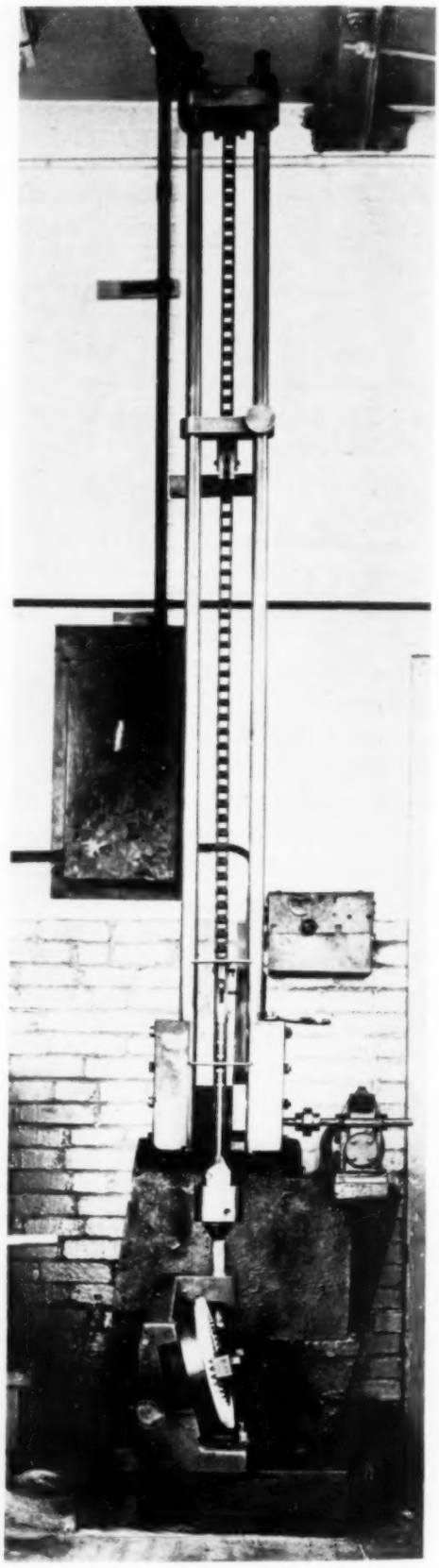
A fixture such as the one described must be made very accurately in order to give satisfactory results. A certain amount of interchangeability is possible; that is, it is unnecessary to build a complete fixture for every variation in design. The main steel block will serve for all pinions of the same shaft diameter. Appropriate gear sections would be bolted on for various tooth ratios, and the punch would be adapted to the form of tooth and type of loading.

Impact Testing Machine

Impact tests are also made by the metallurgical department, Brown-Lipe-Chapin, with the aid of such a fixture. (Whether a gear tooth in an automobile differential is subject to impact, and whether impact tests really mean much, has been discussed for some time. The question is not so academic as might be supposed, in these days when new designs are put into cars enabling the driver to shift to low gear when the car is coasting at high speed. Certainly the differential receives a load approximating "impact" when a high compression motor suddenly brakes the car.)

For impact tests the machine illustrated on this page is used. It has a 25-lb. trip which, on falling, strikes the punch and the blow is thus transferred to the tooth. The release trigger can be set at any height. A small motor is used to lift the weight and the trigger has an odometer which counts the number of blows delivered.

A test on a drive pinion would require the first



blows to be delivered from a 2-ft. drop (50 ft-lb.). The punch would have, say, a ½x¼-in. contact with the tooth on the central section of the reverse side of the tooth. This area of contact is much reduced from that of the static test, and gives information on another important point; viz., the crushing strength of case and core. As each blow falls, the tooth is closely observed through a reading glass and when the first crack appears, the number of the blow is noted. The hammering is then continued until the whole tooth bulges downward a definite amount. The two views below show the results. Other things being equal, a gear which shows the highest resistance to this type of overload would be best suited for carrying the excessively high tooth pressures at which modern trucks and high speed cars operate.

Ultimate strength of a gear tooth under impact would be determined in much the same manner. On large teeth the trip would be dropped from 6 ft. (instead of 2 ft. for the pinion) thus delivering a blow of 150 ft-lb. The punch would have a $\frac{3}{16}$x1⅜-in. bearing, starting ¼ in. from toe and extending to the heel of the tooth. Number of blows to crack the tooth would be noted, as well as the number to break the tooth away.

Considerable variation may be found in the number of blows to produce the first crack in a series of teeth on the same gear, or in successive gears from the same lot. This may depend on the presence of a small amount of excess cementite in the case, a small slag streak in the steel or a tool mark on the surface — all of which will cause concentration of rapidly applied stresses. It also doubtless reflects a certain lack of uniformity in heat treatment, tooth to tooth, and gear to gear. Planes of structural weakness associated with ferrite banding have also been associated with erratic impact figures. Discovery of this condition has led to a simple change in heat treatment routine which has greatly increased the degree of uniformity of the product — namely, give a longer soak, say ½ hr., at about 1,475° F. in order to distribute the carbon more uniformly in the steel.

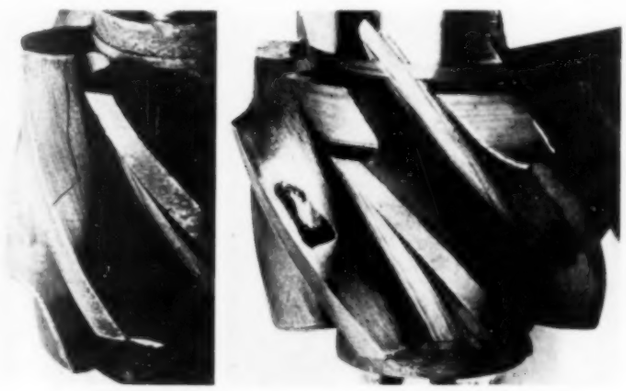
Improvement in Quality of Gears

To indicate how these tests are used to determine the relative excellence of gears, some results may be taken from a series of tests on two steel analyses, submitted to a variety of treatments. The treatment used on the 5% nickel steel pinions tested, consisted of carburizing at 1,650° F.; quenching from the pot in an open tank of cold oil; reheating to 1,380° F.; soaking for 15 min., quench in oil, and draw in oil at 300° F. for 10 min. The treatment used for this particular pinion when made of 3½% nickel steel was to carburize at 1,650° F., cool in the pot, reheat to 1,475° F., soak for 15 min., quench in an open tank of cold oil, and finally draw in oil at 350° F. for 12 min. Results of the physical tests on the completed pinions follow:

	5% Ni steel	3½% Ni steel
Depth of case	0.06 in.	0.06 in.
50 ft-lb. blows		
For first crack	275	8
To bulge tooth	1506	150
150 ft-lb. blows		
For first crack	23	1
To break tooth	91	31
Static, ultimate load	48,000 lb.	40,000 lb.

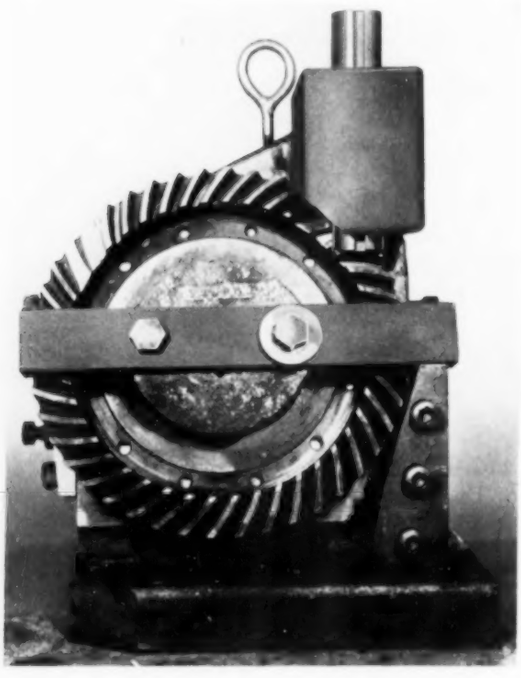
The superiority indicated by these tests for this truck pinion made of 5% nickel steel has been amply verified in later service of the severest and roughest nature.

The fixture for imposing similar tests on ring gears is shown on page 52, and consists of a block of steel with a face inclined at the correct angle so that the surface of the tooth under test



Appearance of Pinion, Tested in Impact, Until First Crack Appears on Under Side of Tooth, and Until Case Is Punched Into Backing a Standard Amount

is approximately horizontal. To fix the gear in this position a binding bar made of S.A.E. 3340 steel is bolted across the face. This binding bar, although smooth on its outer surface, has a series of teeth cut on its inner face which mesh closely with five or six of the teeth on the gear.



Ring Gear Mounted in Testing Fixture, and With Punch in Place for Transmitting Load to One Tooth. The binding bar, bolted across the front, has teeth cut on its rear face which mesh with the gear and prevent it from turning

Cutting these teeth on the binding bar is a job which tests the skill of the best toolmaker. Brown-Lipe-Chapin is exclusively a differential producer, and nearly all of it is spiral bevel gearing "on centers." Teeth on the binding bar are teeth of a hypothetical rack which would be driven by the spiral teeth on the bevel gear.

Slow testing under gradually increasing static load (to determine the elastic strength of the design), impact tests on a small area of the tooth (to determine the crushing strength of the case and core), and impact tests on a whole tooth (to determine its ability to resist shock) may all be made on a gear when mounted in this fixture, and placed in an Olsen tension machine (running in compression), or in the special drop testing machine already described. As a type of the information secured, take the following data indicating the difference in quality in older gears forged from a plate or slab (with parallel flow lines or "fiber" across the face of the gear) and more recent gears forged by the "pancake" or upsetting method, where the flow lines are bent out from a common center and are properly disposed in each tooth. Both gears (which may be taken as representative of the type) were made of 3½% nickel steel, carburized at 1,600° F., cooled in the pot, reheated at 1,440° F. for 60 min. and quenched in oil. In each instance, tooth A was one quarter around the circumference from tooth B.

	Slab Gears		Pancake Gears	
Number of 62 ft-lb. blows to crack				
Tooth A	106	17	69	18
Tooth B	10	5	53	25
Average load to break tooth	22,650 lb.	23,550 lb.	19,320 lb.	18,250 lb.

Note particularly the wide variation in impact strength of teeth at various parts on the ring when made of slabs, and the much more uniform strength when made of upset bars.

It is admitted that the results must be interpreted with great care. Unless the fixture itself is most accurately made, the gear held in it with great rigidity, and the punch which transmits the blow placed on the exact spot on the tooth, the results will be erratic even when testing successive teeth on a gear which service records indicate is of superfine quality. Even when these mechanical precautions are taken care of, the results do not duplicate themselves with sufficient precision that conclusions can be drawn from *minor* variations in the test results. However, experience has amply demonstrated that a change in heat treatment, composition or design (which to the uninitiated might be thought to be of minor consequence) will make an unmistakable change in the numerical results. Furthermore, much valuable information can be secured of a qualitative nature, regarding the gear tooth which, though battered by a number of standardized blows, is still cracked the least and remains in the best shape. The way the tooth breaks down under these tests gives much valuable information.

Cemented

Tantalum Carbide

a new tool material

FOUR TIMES in the past thirty years has the metal working world been introduced to new tool materials—probably as many as in the previous three centuries, so rapidly do we travel! First, the Taylor-White method of hardening high speed steel, then stellite, then cobalt-bearing high speed steel, and finally cemented carbides have successively established themselves as superior tools for definite purposes in mass production.

A recent addition to the last category is known as "ramet": hard and brittle tantalum carbide bonded with strong and ductile nickel. Early performance tests indicate its adaptability for high speed tools to cut hard-to-cut metals and the tough and abrasive fibers and synthetic plastics. It has been perfected by Fansteel Products Co., North Chicago, Ill., after some 15 years of experience in the manufacture and fabrication of rare metals and their alloys and compounds.

Cutting tools of cemented carbide were first made by Fansteel in 1915 and were used in place of diamonds for turning bakelite. The commercial possibilities of this development were pushed aside, however, because War demands for metallic tungsten and the other rare metal products occupied the available men and energy. After the War Dr. Clarence W. Balke, head of the research laboratories, again turned his attention to tantalum and in 1922 he was able to produce pure, ductile tantalum on a commercial basis, as described by METAL PROGRESS for last December. Commercial manufacture of tantalum carbide cutting tools was the result of further research into the characteristics of this unusual metal.

Tantalum carbide has a much higher melting point than tungsten carbide, the hard element of most of the other new tools of this class recently exploited. The approximate temperatures are 4,400 and 2,700° C. respectively. Another characteristic of tantalum carbide is its very low heat conductivity, estimated at about ⅓ that of tungsten carbide. The first characteristic enables considerable leeway in manufacture of the material ramet, and the latter prevents heat from being drawn back from the cutting tip to soften the brazing which joins the molded carbide to the tool shank.

Tantalum carbide cemented with nickel has a yellowish color, a density of 235 grams per cu.in., and a hardness of 89.5 to 90.5 read from the Rockwell C scale with no load. (If the diamond is pressed into such hard specimens under more than the "no-load" weight of 60 kg., the diamond indenter is liable to break.)

Manufacturing operations include the reduction of pure tantalum from the ore, as described in the former article. Carbide produc-

tion is the next step, after which this material is ground to the consistency of lampblack in ball mills. The correct amount of pure nickel is added during the grinding process so that the grains of the final powder will be properly coated with this binding material. The amount of nickel varies with the purpose for which this tool is intended; about 8% is the most usual proportion.

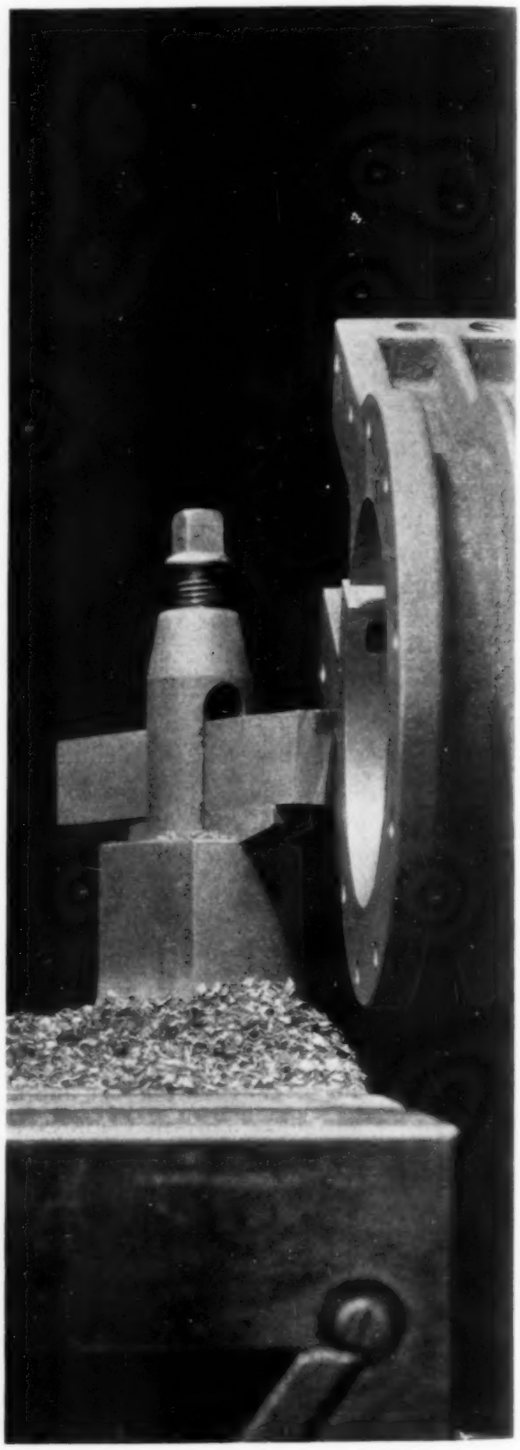
The ground mass is then molded into shape and heat treated, following which it is pressed into final form hydraulically, due allowance being made at this stage for the shrinkage caused by the electric-furnace sintering which follows. Fansteel Products Co. then delivers these molded and sintered shapes of ramet to licensed tool manufacturers or to tool users equipped to make the necessary mounts. The price is competitive with that of cemented tungsten carbide.

It is impracticable to braze, weld or solder cemented tantalum carbide directly to steel tool shanks. The tool tips are therefore nickel plated and given a special heat treatment by the manufacturer. They can then be brazed to shanks, using pure copper in a reducing atmosphere. (A mixture of hydrogen and nitrogen is usually used for this operation, better termed "coppering" than "brazing," since copper rather than brass is the weld metal.)

In both laboratory and commercial tests, tools tipped with cemented tantalum carbide have rapidly and efficiently cut such time-honored bugbears of cutting tools as Hadfield's manganese steel, white cast iron, die cast aluminum, duralumin, bakelite and various bronzes. A satisfactory procedure is to maintain the feed previously established for other cutting materials, but to increase the speed. On some work it is possible to increase both the speed and feed. The life between grinds is stated to be at least equal to that of tungsten carbide tools.

In one of these tests a ramet lathe tool was tried by a machine tool builder in a new turret lathe built especially for heavy duty, high speed work. A 3-in. bar of annealed S.A.E. 1050 steel was turned down to 2 in. in a single cut. The speed was 170 ft. per min. with the feed 0.020 in. The cut, of course, was ½ in. In this test the lathe developed 37½ hp. The tool turned down 100 ft. of this material and at the end of the run was pronounced in good condition, despite the fact that it was worked two and a half times faster

Stage Ring for Vacuum Pump, a Semi-Steel Casting, Faced and Bored With Ramet-Tipped Tool. Other parts of same pump shown at bottom of opposite page. Despite the intermittent cut, the tool removes 5/32 in. of metal and finishes in one cut



than conventional speeds for high-speed tools.

In service the value of low thermal conductivity becomes apparent. The tool does not heat up so fast. Ramet tools can therefore be designed with stronger cutting angles, and there is little possibility that the heat of operation will soften the brazing which fastens the tip to the shank. Very little expansion in tools has been noticed even after severe tests, and they should maintain correspondingly close tolerances in parts cut at high production speeds.

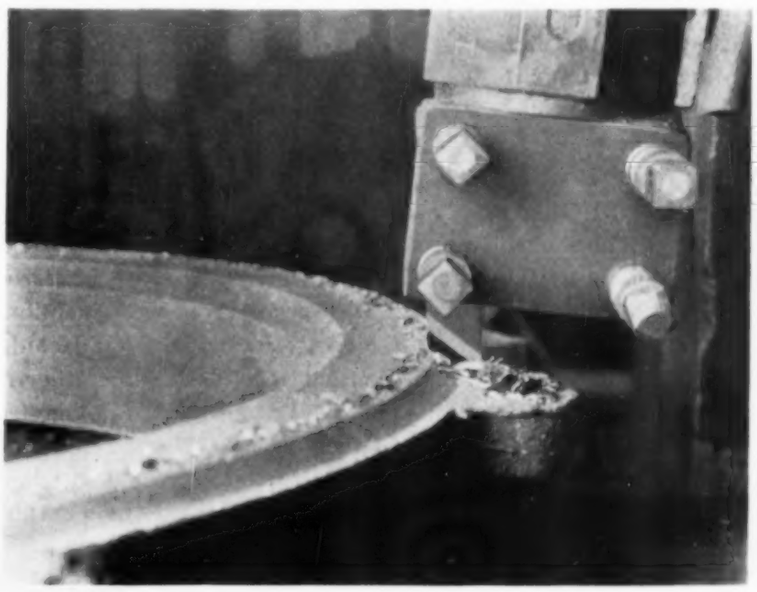
Tools Used on Intermittent Cuts

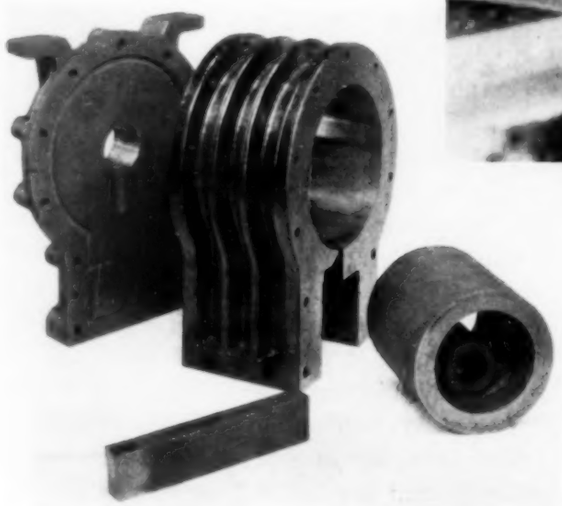
Gear hobs of quenched high speed steel have been efficiently turned, which indicates its ability to withstand intermittent cuts. The tools used for this work had a 10% negative rake.

In another test, a bar of high-manganese cast steel was put on a small and not very modern lathe with its surface as cast, without preliminary grinding. Several drills were dulled before the "non-machinable" steel could be centered. The machine was then run at 135 ft. per min. and was set to feed 0.005 in. No lubricant was used on the tool, which made an ⅛-in. cut along the length of the bar. At the end of the run, the tool shank was found to be cool enough to grasp in the hand and the tip was not too hot to touch.

This coolness, due chiefly to the low thermal conductivity, should have several important effects. First, the chip should not stick to the tip, alloy to it, and build up in a ridge, as has been frequently noticed in high speed cutting experiments. Second, failure of the braze by softening from heat will be less frequent, if not altogether eliminated. Third, tools with smaller inserts or tips can be made than if the tip were a better heat conductor.

Taking 5/8 In. of Scale and Metal In One Cut From a Chill For 33-Inch Car Wheel Mold





A lower amount of nickel used for bonding the tantalum carbide makes for a harder tool, but it then becomes harder to grind and dress and loses some strength. Wire dies may be made of harder mixtures than cutting tools because they are lapped and ground with diamond dust and are not subject to the stresses of machine tool operation. Consequently special mixtures of carbide and nickel can be used.

Why . . .

BY E. E. THUM

did that spring break?

SPRINGS are found in most mechanical devices and most of our comforts depend on their efficient performance. To these millions of unseen, often unknown, springs, whose efficient service usually outlasts all other parts of the mechanism, no one pays any attention unless one breaks. When someone starts investigating he will find that information about springs and spring performance is not very widespread. It will therefore be the purpose of this article to outline briefly the causes of failure which may be looked into, and point out ways to obtain better springs for difficult services.

Spring failures may be due to three general causes: First, poor engineering design; second, poor material, or faulty heat treatment of good material; and third, use of the wrong kind of material to withstand the service conditions.

Engineering Design. It may come as a shock to the reader, but the truth remains that the average engineer does not bother to calculate the stresses in the springs he orders. He will carefully study the loads and induced moments on a shaft or axle, and compare the results with similar determinations for designs which have proved satisfactory and some which have given trouble, but when he selects a spring for even an essential mechanism, he is content to turn to tables in a handbook. The unfortunate part of it is that most of the handbook tables are calculated on the basis of 80,000 to 120,000 lb. per sq.in. fiber stress. Now this is too high a working load for a steel part of indefinite life. It actually is above the endurance limit of nearly all steels. The consequence is that a spring, so stressed, will fail after a few thousand or few hundred thousand cycles of load, where millions were desired. All too often the space allotted is so meager that it is next to impossible to install a new spring of sufficient strength.

These preliminary remarks serve to introduce and justify the first statement:

The commonest cause of trouble with springs is overloading.

It is a common cause of trouble because, as mentioned above, few engineers give the intelligent design to springs that is bestowed on the other machine elements. So the first thing for the trouble shooter to investigate is the stresses set up in the spring during its operation. His method of operation may best be described by assuming a common example and following through.

Let us assume that trouble is being had with a compression spring made of round wire. Its ends are squared and ground. It is a typical valve spring, such as shown standing, at the left of the cut on the opposite page. If some unbroken samples are available, it is easy to weigh the loads required to compress them to their working lengths. A very simple relationship exists between the load, the diameter of the coil, the diameter of the wire (which can all be easily measured) and the internal shearing stress in the steel, which, if too large, will cause rapid

breakdown of the part. Consequently, the investigator can determine at once whether the spring is overloaded.

Stress per pound of load is found by dividing the pitch diameter of the spring by the cube of the wire diameter, and multiplying the quotient by the constant 2.55. Simple enough!

Suppose the spring under examination is made of 0.06-in. steel wire (d=0.06) and the outside diameter is 1.10 in. Its pitch diameter D is the outside diameter of the spring minus the diameter of the wire, or 1.04 in. The relationship given in words just now may be expressed in a formula; substituting the values for the problem in hand and solving, we have the unit stress

$$S = 2.55\frac{D}{d^3} = 2.55\frac{1.04}{0.06\times0.06\times0.06} = 12{,}300 \text{ lb. per sq. in.}$$

which is the stress induced in this spring per pound of load. If it carries 2 lb. its internal shearing stress will amount to 24,600 lb. per sq.in., 3 lb., 36,900, and so on. Obviously, the load must not be too great, else the elastic limit will be exceeded, and then the spring will break before long. Safe values will be given later. The present purpose is to show how easily an experimenter can compute the stresses in a spring for any given load.

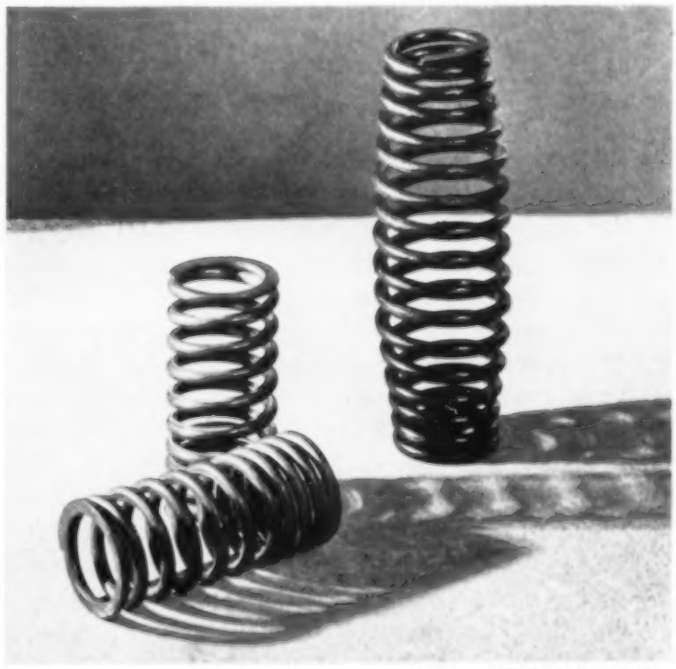
If it is not convenient to proceed as above outlined and the working dimensions of the spring are known, the equivalent loads can be computed by another formula, and from these loads the internal stresses can be calculated as indicated above. The load to compress a helical spring one inch is found by multiplying one-eighth of the modulus of elasticity in shear by the fourth power of the wire diameter and dividing this figure by the product of the number of coils by the cube of the pitch diameter of the spring.

Assume that the free length of the spring under investigation is 0.69 in. and the run of the helix is 0.30 in. Dividing one by the other gives the number of coils N, or 2.3. Expressed in a formula, substituting the measured values and solving, we have the unit load

$$p = \frac{11{,}500{,}000}{8}\frac{d^4}{ND^3}$$
$$= \frac{11{,}500{,}000\times0.06\times0.06\times0.06\times0.06}{8\times2.3\times1.04\times1.04\times1.04} = 7.2 \text{ lb.}$$

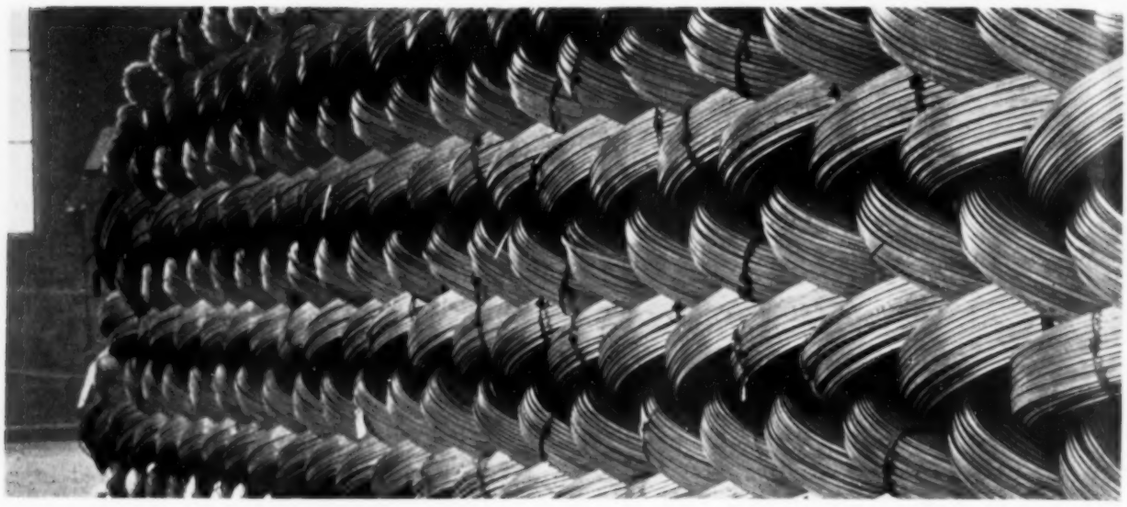
which is the load required to compress this spring one inch.

According to the measurements, the spring's length in operation varies between 0.56 and 0.25 in. The compression is therefore the difference between those figures and the free length, 0.69 in.; that is to say, 0.13 in. and 0.44 in. respectively. The loads required for these deflections are directly proportional to the load just figured and are equal to 7.2x0.13 and 7.2x0.44 or 0.94 lb. and 3.17 lb. respectively. The working stresses in the spring (figured above at 12,300 lb. per sq.in. for each pound of load) therefore vary between the limits of 12,300x0.94 and 12,300x 3.17, or 11,500 and 39,000 lb. per sq.in.



Courtesy Wallace Barnes Co.

These are quite moderate stresses for a well-made steel spring, and if trouble is encountered in service, then the cause is elsewhere.



Safe stresses for helical compression or tension springs made of wire less than $\frac{3}{8}$ in. diameter are given below.

Even these stresses should be used with discretion. The smaller the stress range, the safer the spring. Where possible, springs should be designed so the stress range is not over one-half to one-third the maximum working stress. For example, a tempered wire spring, whose stresses range between 25,000 and 60,000 lb. per sq.in., should give many millions of load applications, whereas the same spring operating from 5,000 to 60,000 lb. per sq.in. would be dangerously near the fatigue limit. These statements are contingent on the spring working under non-corrosive conditions. There is no surety of spring life if the springs corrode, because the highest stresses are at the surface, just where corrosion sets up the greatest troubles with its pitting and notching ("stress raisers", as they are called by Prof. H. F. Moore).

The 1-in. spring whose stresses were calculated in the above example should be all right if made of hard drawn spring wire. The range of working stresses on this spring (11,500 to 39,000 lb. per sq.in.) is well within the maximum noted in the table at the bottom of this page for hard drawn spring wire.

It is well to recall, however, that rather small dimensional changes in a spring may have unexpectedly large results in the internal stresses and the resulting service.

The mathematical equations already given obviously make no allowance for any variation in size or quality. Commercial limits on the diameter of tempered wire are plus or minus 0.0015 in. This introduces an error, the value of which depends on the other dimensions of the particular spring in question. Furthermore, in coiling springs from commercial wire there is often a difference in the outside diameter, even when made of the same coil of wire. This is due to variations in tensile strength and elastic limit of the raw material with consequent variations in the amount the spring will recoil or unwind when released from the arbor. In cheap wires this variation will often be $\frac{1}{32}$ in. in a spring 1 in. in outside diameter. The designer should allow for these commercial variations; if the springs must be extremely accurate, only the best materials obtainable may be used and the producer must apply a rigorous inspection.

Material	Maximum Working Stress Lb. per Sq. In.	Maximum Solid Stress Lb. per Sq. In.	Modulus of Elasticity in Shear Lb. per Sq. In.
Steel music wire	60,000 to 70,000	110,000 to 120,000	11,500,000
Oil-tempered wire	50,000 to 60,000	80,000 to 100,000	11,500,000
Hard drawn spring wire	40,000 to 50,000	60,000 to 80,000	11,500,000
Monel metal	25,000 to 35,000	60,000 to 70,000	9,200,000
Phosphor bronze	25,000 to 35,000	60,000 to 70,000	6,250,000
Spring brass	20,000 to 25,000	40,000 to 50,000	5,500,000

throwing out a good proportion of the regular production. This costs money.

As an indication of the magnitude of such commercial variations in an inexpensive spring, the compression spring first described may be recomputed. The wire may be 0.063 instead of 0.06 in., the spring diameter 1.07 instead of 1.10, its number of coils 2.2 instead of 2.3, and the compression ranges through a cycle between 0.16 and 0.47 in.

The stress range for this spring is now 14,500 to 42,800 lb. per sq.in. and it can be seen that the small changes in dimension of the spring occurring in commercial production have increased the maximum stress 10%. If the spring were designed to work near its endurance limit, the commercial variations in manufacture would produce many springs which actually would be stressed beyond safety, and failure of these after relatively short service might be expected. Ordinarily it would be far better to use a spring of ample strength than to skate near the danger line, even if you could afford to have 100% inspection which would throw out all stiff coils.

Included in the table on page 58 is a column of figures headed "Maximum Solid Stress". If a compression spring is wound with too great a free distance between coils, and it is overloaded at any time, it will acquire a permanent set. Its free height will then be less than it was orginally, and the amount of "push" which it exerts at any deflection is less than desired. However, if the design is such that the internal stress is less than that given in the table when the spring is squeezed down solid, coil to coil, the elastic limit will not be passed, and the above troubles will be avoided. This, of course, refers to occasional overloads. Frequent stresses to the figure given will cause fatigue breakdown.

While the above calculations have referred to compression springs, extension springs are the same as far as all mathematical calculations go. Overstressing on tension can be avoided only by having a solid stop to limit the travel.

One peculiarity of tension springs may be mentioned here. The wire coils can be wound so tightly together that a considerable force is necessary to separate the coils. This force is called "initial tension". How such a spring is made should be obvious. In winding compression springs on an arbor, the guide moves forward as rapidly as the helix grows, and the winding wire is always tangent to the helix. If the spring is to be a tension spring wound snugly, the guide moves forward at the same speed, but always lags a certain distance behind where the wire should be if it were to lead in tangentially.

Initial tension may easily cause a fiber stress of 10,000 to 15,000 lb. per sq.in. Such a winding will produce a spring which will resist permanent stretch until loaded a corresponding amount, but no "exact" springs (that is, springs which have a precise length for each definite load) can be made with initial tension, since

small variations in winding have a marked effect on them.

None of these simple formulas, nor other calculations, can predict the flutter or vibration period of springs subject to high speed cam action. Such a vibration will often cause breakage, since the operating stresses in certain coils may be much higher than the average static calculated stresses. This is the commonest trouble with valve springs.

Calculation of the period of the spring does not of necessity indicate which harmonic will be the worst nor what its amplitude may be. About the only practicable way to make an analysis of this phenomenon is to use one of the slow motion devices on the market, as strob-orama, stroboscope or vibroscope. After viewing operating conditions, springs can often be redesigned to minimize this fault.

One note about stresses in tension or compression springs coiled of square wire, and then we will pass to the next cause of spring breakage: The formulas for square wire are the same but the constants are different. Maximum internal stress per pound of load is found by dividing the pitch diameter of the spring by the cube of the wire size, and multiplying the quotient by the constant 2.25. In the other formula (load to compress spring one inch) the constant is modulus of elasticity in torsion divided by 5.58. (It may be noted that frequently this divisor is quoted erroneously at 5.25.)

Now consider the second cause of spring breakage, namely, faulty material and heat treatment. The usual ferrous materials used in helical coiled springs are S.A.E. 1350, 1360, 1065, 1075, 1095, 6150, 9250, music wire, and stainless steel. In the non-ferrous metals we find spring brass, phosphor bronze and monel metal to be largely used. It would take too much space to discuss each of these materials in detail, but it will be valuable to include some general remarks. (A more detailed article on steels used for fine springs was given in October's METAL PROGRESS.

In steel wire ⅜ in. diameter and smaller, it is rare to find coarse grain or poorly heat treated material. In the larger sizes this is not uncommon nor are deeply decarburized sections as scarce as could be desired. In properly designed springs of the smaller wire sizes, Barnes-Gibson-Raymond finds 90% of all spring breakage to be due to surface defects. These can be most easily seen by hot acid etching; 10 min. in a boiling solution of 30% hydrochloric acid will throw much light on the cause of breakage from surface defects, bringing, as it does, seams, scratches, cuts, pits, or dirt into view. The photograph on this page shows two such samples. The coil was evidently made of overdrawn wire, and the acid has eaten a series of gashes, some of them half through the wire, all ranged at approximately the same inclination to the center of the wire. Music wire is sometimes defective, also. The S-shaped sample in the photograph has a hair-line crack extending down one element of the surface.

Springs are sometimes heat treated incorrectly with resulting coarse grain. This can be determined by the fracture of the wire and microscopic tests.

No doubt it is the duty of the spring maker to inspect the wire he buys, and make every

effort to eliminate off-grade metal before it gets into production. Barnes-Gibson-Raymond is particularly careful on this point. All its material is bought from manufacturers who are thoroughly acquainted with the requirements of first-class springs, and who will accept its specifications for the kind of wire on order. On delivery, a 3-ft. piece is clipped from each end of each coil and sent to the main laboratory for routine tests. The most searching physical test and the one on which most reliance is placed is in torsion. Three 12-in. samples are twisted in a triple torsion machine, a certain number of turns and then double the number in the opposite direction. The exact number depends upon the kind of wire, its size and heat treatment. The view on this page shows results of a very severe test on 0.148-in. wire: 17 twists in 10 in. and reverse. Good wire will twist uniformly end to end and break off square without necking and with a smooth shiny fracture. Poor wire will crack and break after a few twists, either direct or indirect, in a jagged or inclined break.

After such testing the only way for bad wire to get into production is when the test piece from the end of the coil does not represent the rest of the material. Variations in quality, end to end of a single coil of wire, may be due to pipe or segregation in the original ingot, improperly chipped billets, local overheating prior to rolling, or delay in rolling so that the trailing end of the rod is finished much cooler than it should have been.

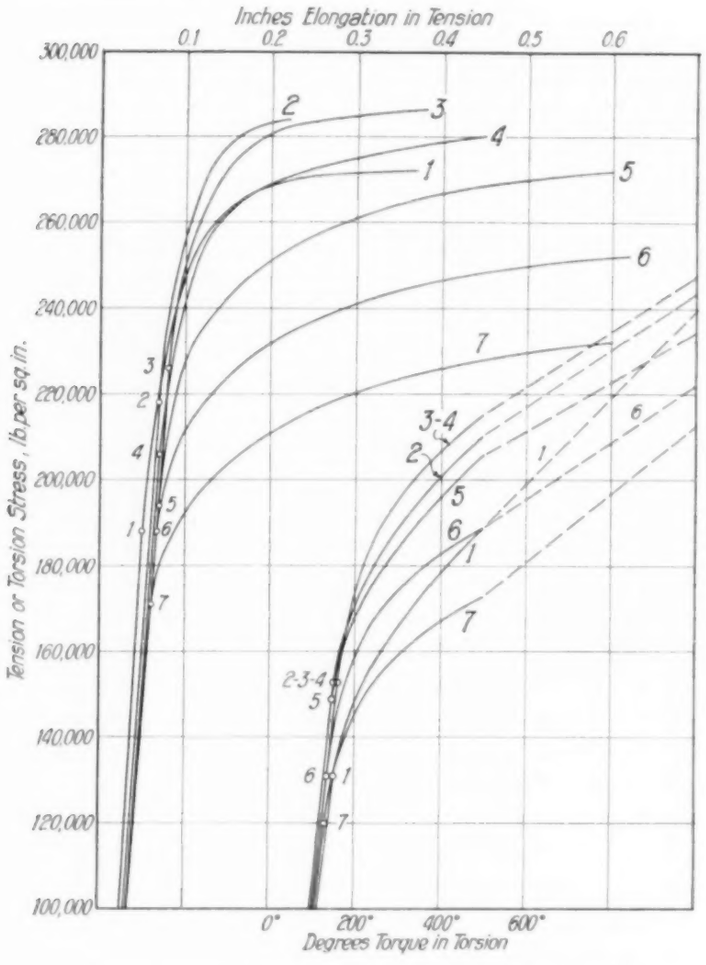
The hardness of springs is also a possible fault. For carbon steel helical springs a Rockwell hardness on sizes below $\frac{3}{8}$ in. usually runs 40 to 45 on the C scale. Chrome-vanadium steel (S.A.E. 6150) will stand slightly higher figures. Manifestly the harder the steel, the higher the tensile strength, and, based on Professor Moore's work at the University of Illinois, the higher the endurance limit.

Against this, one must balance the fact that the harder steel is more brittle and the secondary stresses caused by surface marks or inclusions will be much higher, since the plastic flow and consequent formation of fillets by the material itself is more difficult the harder the steel. For this reason a spring should be heat treated so that it will be no harder than necessary to have an elastic limit high enough to carry the desired loads.

As an example of what might be expected in ordinary practice with carbon and alloy valve spring wire 0.162 in. diameter, the typical figures

Pickling Indicates Defects in Spring Wire. A hair-line crack is shown down the side of the S-shaped sample of music wire. The fragment of a coiled spring shows evidence of being made of overdrawn wire

Good Spring Wire Can Be Twisted and Untwisted, Finally Shearing Off Square. Poor wire will crack after a few turns, and soon break on an inclined surface



Stress-Strain Curves for 0.112 in. Music Wire

Curve No.	Tempering Temperature	Rockwell Hardness	Tension Test					Torsion Test	
			Elastic Limit	Ultimate Stress	Elongation in 8 in.	Elongation in 2 in.	Reduction of Area	Elastic Limit	Ultimate Stress
1	as received	C-48	188,000	272,000	3.1%	6.2%	51%	131,000	240,000
2	300°	C-49	218,000	284,000	1.5%	3.1%	46%	153,000	244,000
3	400°	C-51	226,000	286,000	2.3%	3.9%	47%	153,000	248,000
4	500°	C-51	206,000	280,000	3.1%	6.2%	44%	153,000	248,000
5	600°	C-50	194,000	272,000	4.7%	6.2%	43%	149,000	235,000
6	700°	C-49	186,000	252,000	4.7%	7.0%	44%	135,000	223,000
7	800°	C-46	171,000	252,000	5.4%	9.3%	38%	120,000	214,000

are submitted in the tabulation on page 63.

The figures indicate a considerable superiority in proportional limit, and reflect the general impression that chrome-vanadium steels can stand 10 to 12% more than carbon steels. Against this must be noted the difficulty in getting alloy steel wires with as good surface condition.

Note also that the above tabulation is for 0.162-in. wire. As size increases the physical properties decrease, so that 180,000 ultimate tensile is about all that can be expected of $\frac{3}{16}$-in. wire. On even larger sizes, $\frac{3}{8}$ in. to 2 in. diameter, the hardness will drop from 420 to 350 Brinell.

The surface is also much poorer than in the smaller sizes, with consequent reduction of available stress ranges. To determine these points the microscope and acid etch are of great importance and must not be neglected.

Music wire is a chapter in itself, since this wire is strengthened entirely by cold work. There is no possible heat treatment that will give as good physical properties to quenched and drawn material. The only treatment that will improve properly drawn music wire, after forming into coiled springs, is a simple heating to from 475 to 525° F. for 20 min. Continued heating at higher temperatures will only harm it, as is shown by the stress-strain curves made under the direction of F. P. Zimmerli, chief engineer, Barnes-Gibson-Raymond, Detroit, both in tension and in torsion, after various draws. A prolific source of trouble with music wire springs comes from heating them to around 700° F. after coiling, imitating good practice for mill-tempered spring wire.

The third cause of trouble, namely, the use of the wrong material for springs in varying installations, is not uncommon. To combat corrosion, monel metal, phosphor bronze and brass are often used. None of these non-ferrous metals seem to have a true elastic limit, and therefore are subject to plastic flow under load with consequent loss of resilience. They are normally designed for 30,000 to 35,000 lb. per sq.in., maximum stress. Whether these materials have a real endurance limit, like the ferrous materials, is still being debated. It probably is less than 25,000 lb. per sq.in. Failures of monel metal springs have occurred in chemical pumps after 3,000,000 stressings to 15,000 lb. per sq.in., when no corrosion was evident. Consequently, such

springs must be subject to low stresses and even then may not give many million stress reversals before fatigue failure. For heat resistance, monel seems to be best.

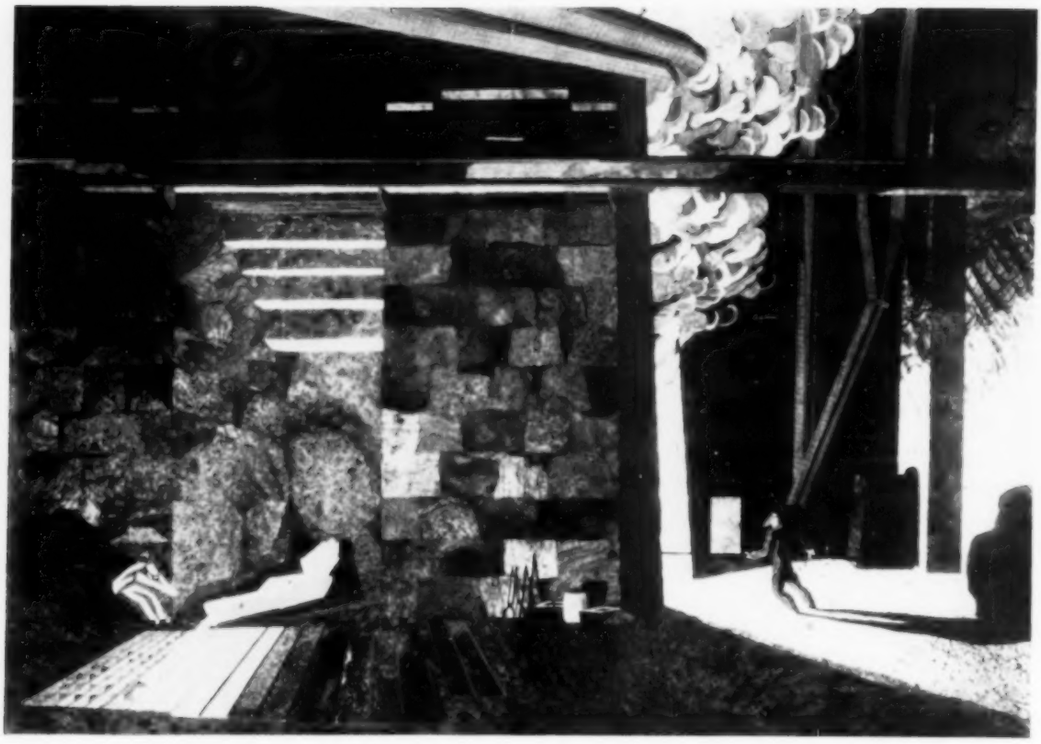
To combat corrosion, where steel must be used, the purest iron-carbon alloy should be used. The highest grade alloy steel, as 6150 for example, will not have the endurance of a plain carbon steel under such conditions. Stainless steel lies between the non-ferrous and the steels.

To combat heat, use a steel with the maximum carbide concentration. Thus S.A.E. chrome-vanadium 6150 is better than S.A.E. plain carbon 1075, even though the latter has 0.75% carbon to the former's 0.50%, since under corresponding conditions the microstructure of the former will show more free carbide. Likewise S.A.E. 1360 (medium manganese) is better than S.A.E. 1075. As would be expected, high speed steel can be used and will stand reasonably high operating temperatures. It has been successfully used at 850° F., but with correspondingly low fiber stress: 35,000 lb. per sq.in. with Rockwell hardness 44 to 46.

This sketchy outline has said nothing of torsional or power springs, nor of leaf or elliptical springs. Nor has it entered much into the exact heat treatment of the steels. It has only scratched the surface of what might be said about the commonest tension and compression springs, and said it in elementary terms, hoping thereby that metal men and spring users generally will have a better idea of the problems involved in spring making, and more specifically, what they can do to avoid difficulty and disappointment in the use of these essential machine elements.

Typical Values of Alloy and Carbon Steel Wire

	Chrome-Vanadium Steel	Carbon Steel
Chemical analysis		
Carbon	0.51%	0.75%
Manganese	0.62	0.32
Chromium	1.12	
Vanadium	0.15	
Phosphorus	0.021	0.027
Sulphur	0.029	0.019
Tension test after heat treatment noted below		
Ultimate strength	215,000	210,000
Proportional limit	196,000	180,000
Reduction of area	47.5%	52.5%
Elongation in 2 in.	6.25%	7.8%
Rockwell hardness, C scale	45 to 47	42 to 44
Torsional properties after heat treatment		
Ultimate	161,000	158,000
Proportional limit	119,000	110,000
Heat treatment		
Oil quench from	1,625° F.	1,425° F.
Draw at	825° F.	750° F.



ADORNING the directors' room, Bofors Steel Works, Vermland, Sweden, are six beautiful panels in inlaid wood, the work of Ewald Dahlskog. The artist's medium — inlaid wood — is unique, and has enabled him to achieve high contrasts and unusual cloud effects. Notable also is the virile representation of these scenes from the steel plant, scenes portraying the oldest days of hand labor and the most modern and powerful mechanical equipment. Undoubtedly they are a continual reminder to the men at Bofors of a tradition of good work, well done by skilled men.

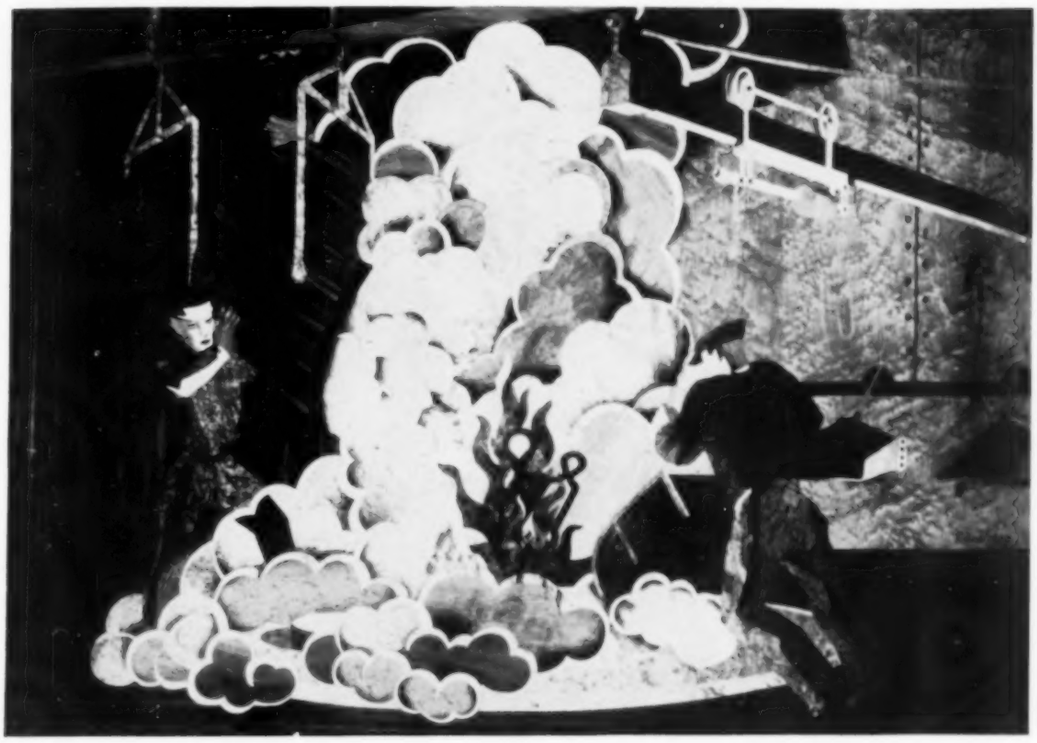
The photographs which are reproduced at the head of these six editorial pages were loaned by Naboth Hedin, New York manager of the American-Swedish News Exchange. METAL PROGRESS is happy to be able to print them and thus give all members of the American Society for Steel Treating pleasure in them, not only because of their great artistic merit, but because they strikingly depict metal progress in the most literal sense of that expression.

Editorial

ON THE FIRST visit the writer ever made to Detroit, about 15 years ago, he was surprised to find a steam hammer in the Cadillac plant smashing up steering knuckles and other small forgings — or at least attempting to, for nearly all of them would bend flat and into grotesque shapes before any crack would start. He was told that these cold forgings represented samples from each lot after final heat treatment, and that they "were being tested!"

Such brutal treatment seemed to have little relationship to the standardized tension test and chemical analysis under which the raw steel was bought. Neither did it have much relationship to the duty expected of the parts. Nevertheless, it was an impressive demonstration that in normal running or in accidental smash, forgings in Cadillac cars would bend but not break. And that was the assurance which the car builders needed, and which they did not get by the more conventional tests and inspection methods.

In the intervening time, an increasing number of



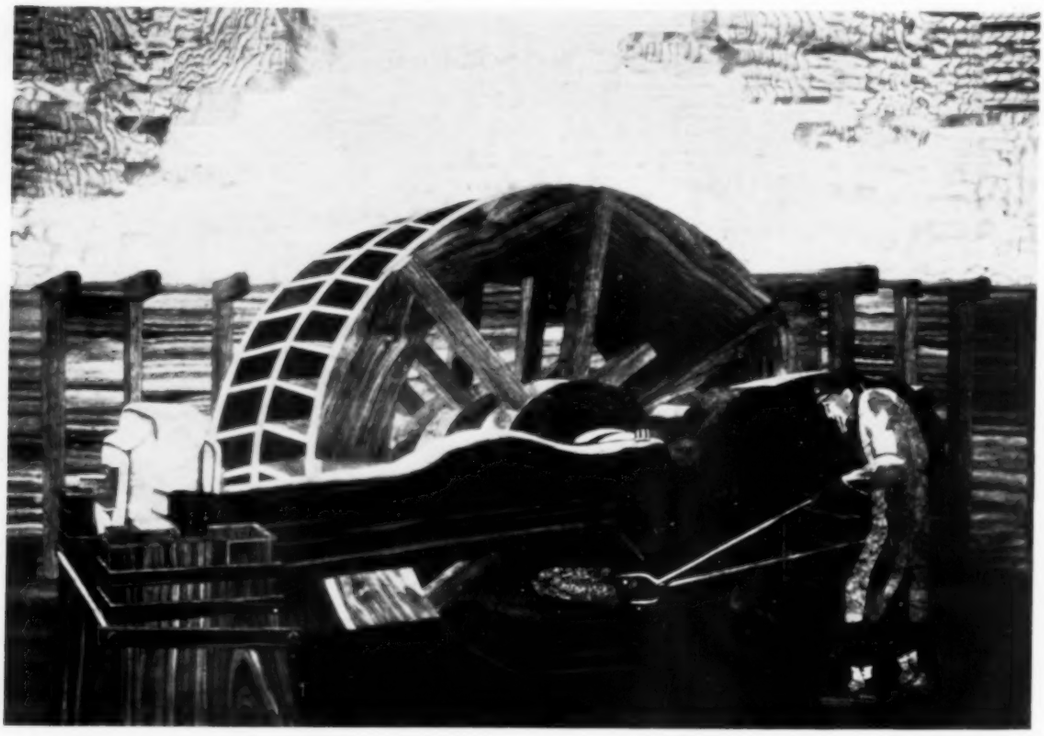
specialized tests has been observed in use by various machinery builders. Some of them were illustrated in President Watson's paper before the Western Metal Congress, printed last month. Others are mentioned in Mr. McCloud's contribution in this issue. Gear testing fixtures are also described in detail on page 47. Many other instances could be described.

This unusual amount of specialized testing probably does not indicate that the engineer who makes machinery is distrustful of the standardized tests designed to evaluate some simple property of the raw material — such as tensile strength or hardness. But it does mean that he is not willing or able to translate the results of these so-called quality tests into figures which indicate the *serviceability* of the part. As Mr. Raab points out, the ultimate tensile strength has but an obscure relationship to the number of miles a transmission gear will drive a Buick sedan. In fact, the testing fixtures so frequently observed in manufacturers' laboratories are exclusively designed for tests of the factors which mean serviceability.

A very good reason exists for testing a completed part, even though the maker were sure it were made of sound steel. He would not wish to buy his steel solely on the result of the ladle analysis or a furnaceman's test-ingot. Too many things happen in the subsequent manufacture; it is obviously unsafe to predict the properties of the forging billet from tests on the ingot. Similarly, it would be equally unwise to assume that this steel could not be damaged — or, on the other hand, vastly improved — by the forging heat, the forging, the cooling, the normalizing, the machining, the carburizing, the hardening, the tempering, and the grinding. The only way to integrate all these factors is to test the part after it has been finished.

Specialized testing of this sort also indicates that more study should be given, in an organized way, to the problem of serviceability tests. Even though machinery wears out, rusts away, and breaks down by fatigue, our testing engi-

Editorial



neers are yet groping for a wear test, a corrosion test, a fatigue test — short-time laboratory tests which have definite relationship to the results of long-time exposure. Lacking such methods of quick appraisal, the development of better materials cannot progress in rational manner. We must wait for some innovation, and for several years after listening to the blandishments of the persuasive salesman, we can only hope that he was right, and that the new material will not lose its bright shine on exposure to city smoke.

Standardized tests for some special quality, such as tensile strength or hardness, are, therefore, being relegated to the role of comparing successive lots of metal to a former one which has proved satisfactory. In other words, a satisfactory gear, axle, rail, or shaft has been devised or discovered by an intelligent combination of science, art, and skill, and it has proved to be satisfactory in service. The problem is to duplicate this satisfactory part until a better one can be devised. For this duplication, the simple tests are useful. But — and this is a point worth noting — merely one test is seldom acceptable.

In addition to a tension test showing proper strength, elastic limit, and ductility, a chemical analysis is frequently specified — or if not specified, actually used in the manufacturer's laboratory to make doubly sure. Furthermore, much steel for important parts must pass a deep etch test, a grain size test, be properly responsive to carburizing, and harden uniformly on quenching. All these are *quality* tests, of a sort, to reinforce in some particular a standardized physical test which is incapable of distinguishing between two steels, one of which will be satisfactory in a rivet snap, for instance, and another which will give trouble.

The progress already recorded in the art and science of testing leaves little to be desired insofar as *progress* itself is concerned. We have increased our knowledge in the past few years but we still have a lot more to learn in this line. The future promises well.

Editorial

Editorial

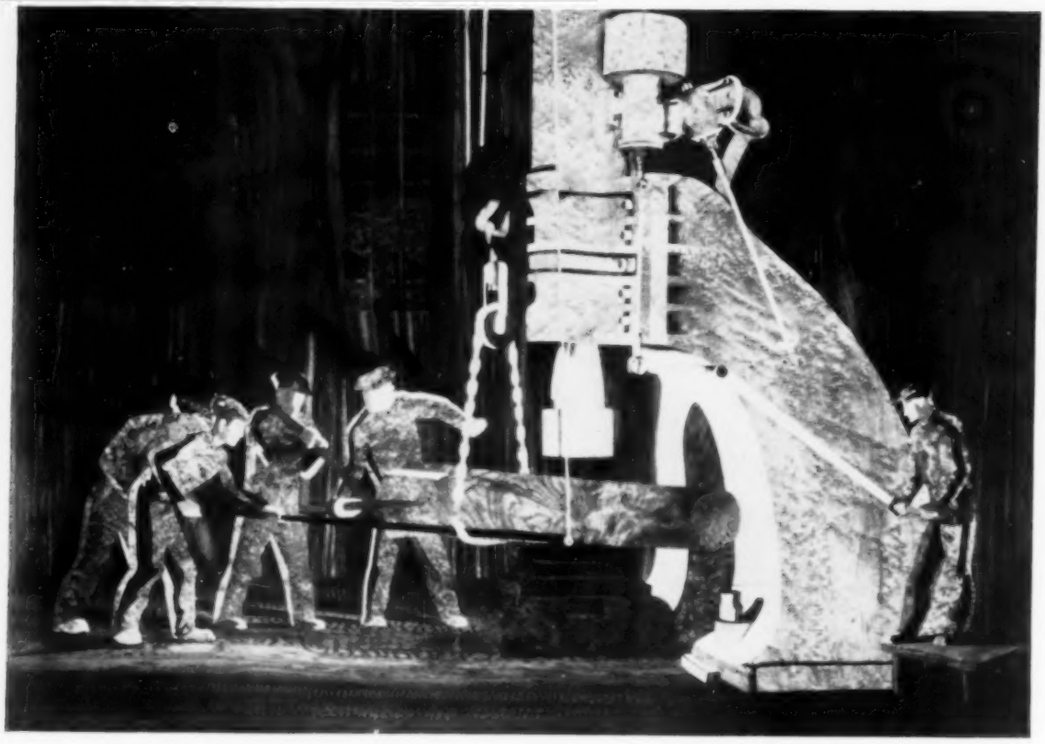
A NON-TECHNICAL contribution to the "Correspondence and Foreign Letters" department (page 89 in this number) is made by Arthur T. Clarage, president, Columbia Tool Steel Co. It doubtless was prompted by the flood of papers which appear during New Years, reviewing all possible phases of human activity. Many of them (especially those of the business economists) are foolishly optimistic, and fully warrant a counterattack.

A casual reader of the letter might conclude that Mr. Clarage is unduly pessimistic and is crying, with the preacher, that "all is Vanity." His principal thought, however, undoubtedly agrees with the sentiment that christened METAL PROGRESS — namely, that advance from an industrial and cultural depression does not consist in re-establishing the conditions of past years, but advancing to a firm position on a new foundation. The past is dead and gone. It ought to be buried. What is there ahead? Men or businesses buried in the past soon decay. They thrive on progress.

FATIGUE endurance, surface condition, and corrosion are closely correlated and have major influence on satisfactory performance and life of machine parts, tools, and major structures. Most metal rusts away rather than wears out. Failures in service are mostly fatigue failures. Fatigue failure ordinarily starts at some imperfection or corrosion pit on the surface. Hence the importance of good surface conditions — a thought often emphasized in metallurgical literature.

There is, however, another aspect of surface which is getting belated attention. This refers to the working properties of thin sheet, strip, or wire — material which is nearly all surface.

Seldom a day passes when a metallurgist connected with sheet steel or brass manufacture is not asked to advise on some trouble in some customer's plant. Material which in former shipments acted satisfactorily in a stamping or coiling operation suddenly gets balky and gives a ruinous number of rejects. Yet in



size, thickness, hardness, and appearance, the metal seems to be quite usual and normal.

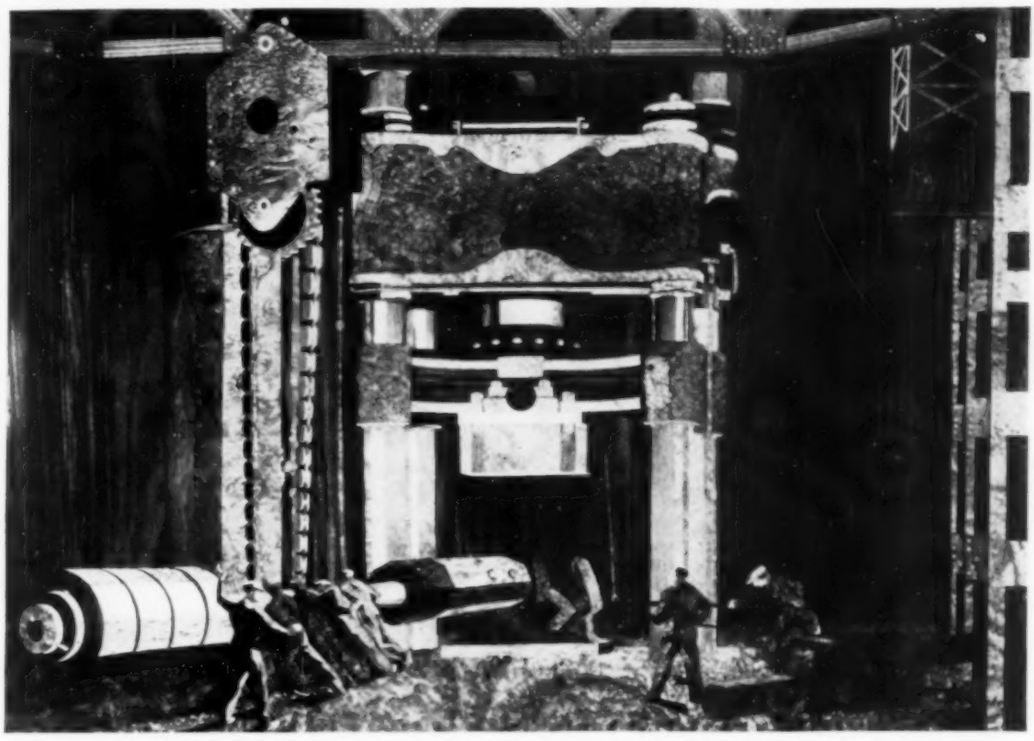
The analysis of the metal proves to be within specification — and only a few years ago everything was supposed to be all right if the sulphur and phosphorus were low enough. More recently some of us have acquired the habit of solving problems by the microscope — but in most cases of trouble-shooting, the structure will be normal, grain size OK, metal good and clean. Next the tensile properties will be tested, but rarely will any clue be found there — good values, both absolute and relative, are returned by the laboratory.

These tests will exhaust the possibilities of most control laboratories. Some, perhaps, will attempt to investigate the difficult matter of internal stress. But it all too frequently happens that strip which gives all kinds of trouble in a customer's plant is normal by all these tests, and as far as can be found, had received normal treatment in rolling, annealing, pickling, finishing and the various other manufacturing operations before it was delivered.

Editorial

Faced by such a mystery — and they are by no means infrequent — the metallurgical detective, trouble-shooter, or whatever you want to call him, is reduced to the necessity of playing "hunches." Sometimes the trouble appears to be psychological — a replacement shipment from the same warehouse bin has been known to relieve the situation! Whether the trouble is in the metal or in the amount of abuse it receives in later fabrication is always a question, but in times such as these where business is scarce and competition sharp, a metal manufacturer cannot afford to blame his customer's shop practices.

Nevertheless, it is well known that a minor change in the amount or kind of lubricant used on the dies will have a great difference on the production of stamped articles. Furthermore, the speed of the operation has many and far-reaching effects, other than testing the ability of the strip to deform under impact loadings. As the temperature of the dies increases, the



clearances change, but this is a minor matter compared to the variation in coefficient of friction between die steel and strip. It would almost seem that a warm die has a surface condition which favors molecular seizure of the surfaces in contact.

Even allowing the full influence of such factors as exist in the press shop, and, therefore, out of control of the strip manufacturer, there are some obscure surface effects undoubtedly due to variations in annealing, pickling, or rolling practice. Successful enameling, for instance, requires a special surface. Some think that minute pits, wherein the glaze can anchor itself to the metal, are the desired conditions. It is more probable that an oxidized layer of submicroscopic dimensions is more essential (at least for non-ferrous alloys).

Such information as this is still reposing in the "practical" man, and as long as he has the most of the information, experimentation will be by rule-of-thumb. The situation is about the same as existed 20 years ago in the art of heat treatment. An equal opportunity exists for engineers and production men to associate themselves in an active organization for an interchange of ideas and data.

Obviously, a new technique must be developed to study these obscure surface phenomena, and this can be taken care of by the scientific-minded members of the fraternity. They, in turn, will need close contact with conditions as they exist in the shop; they will need to be told the trade "secrets" that most of the shop superintendents already know. Judging from the success of the American Society for Steel Treating, everything is to be gained from a sincere effort to systematize information about metal surfaces.

The advantages of whispered shop secrets and practices compare about as well with recommended practices and standards as a locomotive of Civil War time does with one of the modern kind. The trend which brought knowledge to the many instead of the few was largely responsible for this era's progress.

Editorial

Permanently Accurate

to the millionth . . .

BY CHARLES M. POND

EVERYONE connected with the production of metal parts is familiar with the gages which determine the accuracy and interchangeability of metal parts. Everyone whose shop experience dates back 15 years can remember the steady growth in use of precision gages, starting in those hectic war times when manufacturers scattered all over the country were making minor parts of fuses, guns, and other munitions, to be assembled at some central spot with parts made in other far distant shops. That first experience doubtless impressed the real meaning of "interchangeability" upon American manufacturers, and taught them to appreciate the value of master standards whereby the accuracy of the gages used in the workshops could be verified.

In prewar times these master standards in the form of gage blocks were a foreign-made specialty. Existing sets were requisitioned by the War Department and apportioned where the need was greatest. Intensive work at the Bureau of Standards by William E. Hoke devised means whereby small pieces of steel could be made with flat, parallel surfaces, and invented a simple method of inspecting their accuracy and comparing their size with known standards. Pratt & Whitney Co., Hartford, Conn., put these ideas into production, later acquiring all patent rights, and now we have in America an organization capable of producing gage blocks each with an accuracy to within a few millionths of an inch.

Production of these high precision instruments in quantity, and at a price which enables even a moderate sized shop to own a set, is an achievement of mechanical and metallurgical skill. From a metallurgical standpoint the problem is anything but easy. The blocks must be as hard as possible (to prevent wear in use) yet free from internal strain, and so stabilized in internal structure that there is no tendency for change in dimension with passing time. "No tendency for change" takes on added meaning when a piece of steel is to be accurate to within two or three millionths of an inch when it reaches the purchaser, and must not grow or shrink more than one or two millionths with passing years. Theoretically, a hardened steel is in a metastable condition — and a metastable condition with no tendency to change seems to be a contradiction of terms. Yet the Pratt & Whitney special seasoning treatment for Hoke blocks so balances the atomic forces inside a

quenched block that this condition is reached.

Consequently, the precision gage block of today has a very definite mission — it is the master standard constantly available to shop and laboratory alike, giving any desired length, accurate to millionths of an inch. To perform this mission the block must

1. Be accurate to millionths of an inch
2. Have gaging surfaces flat and parallel within millionths of an inch
3. Be hard
4. Be absolutely stable in dimension
5. Reflect the precision which has been worked into it.

To amplify these statements somewhat:

In comparatively few instances would it be necessary to have a single block accurate to within a few millionths of an inch — for instance, a 4-in. length. Combinations of blocks, where an odd size like 3.0517 in. is available in a few minutes, are most useful. Errors in individual blocks must therefore be kept to a minimum so that in no case will the combination of blocks result in a gross error which would seriously affect the measurement being taken.

Flat and parallel surfaces are absolutely necessary with accuracy. Without these two requisites, measurements taken at different points on the block might be different and it would not be possible to "wring" a number of blocks together.

The precision gage block of today must be more than accurate in all essential elements — it must be hard enough to withstand ordinary use under shop conditions, and to give maximum life under laboratory conditions where even the slightest wear is a serious factor. Pratt & Whitney Hoke blocks are subjected to a special hardening treatment, resulting in a minimum Rockwell C 67.

Hand in glove with hardness is stability. This most important feature will be discussed in detail below.

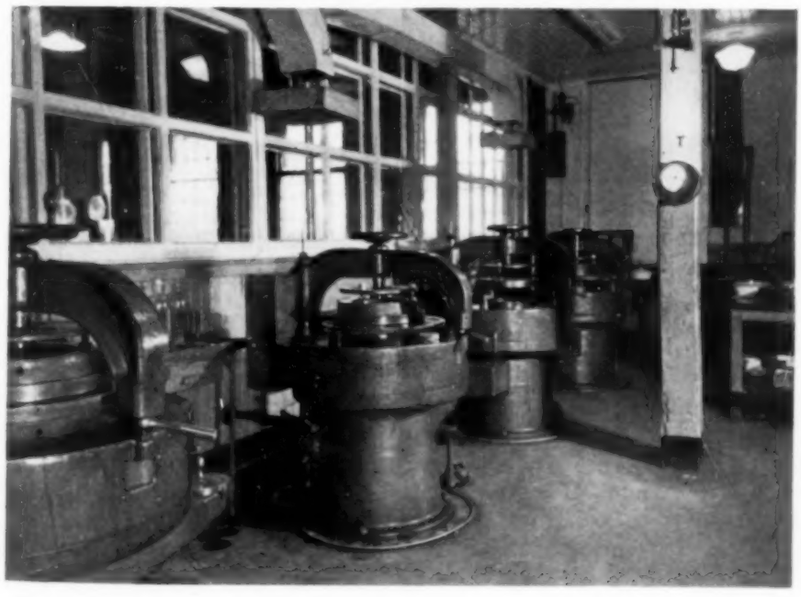
Since the gage block is the standard of every shop, it must command the respect due that position. Lack of respect breeds lack of confidence in the mind of the user, followed by carelessness and neglect which will directly affect the interchangeability and quality of the product.

A review of some of the features of the manufacturing processes is interesting, especially since precision is the keynote in every operation.

Material. One of the first and most difficult tasks in the manufacture of precision gage blocks was the discovery of the most suitable material. Many steels have been tried, including carburizing grades, tool steels, and alloy steels.

A high carbon chromium alloy steel has been finally adopted. This is of the deep hardening type, and possesses a very fine-grained structure after proper treatment.

Great care is required to manufacture the steel, and the rough



A Battery of Precision Lapping Machines in a Constant Temperature, Constant Humidity, Workshop

bar inspection must be correspondingly thorough. A chemical analysis and physical examination of each bar in the shipment is made, including micro-examination and fracture test. The entire lot of the material is either accepted or rejected on the basis of this 100% inspection.

Roughing operations. Incoming bars are $1\frac{1}{16}$ in. square. The first manufacturing operation is to grind all four sides to remove any surface defects which might be present. Bars are then held in stock for approximately six months. As required, the oldest bars are withdrawn from stock and cut to proper length for the blocks under order, plus a proper machining allowance. This operation is done in multiples, using a Pratt & Whitney semi-automatic milling machine with a gang of cutters. Then follow in succession the operations of grinding the faces, burring the corners, drilling, reaming and countersinking the center hole. The blanks are now finished and ready for heat treating.

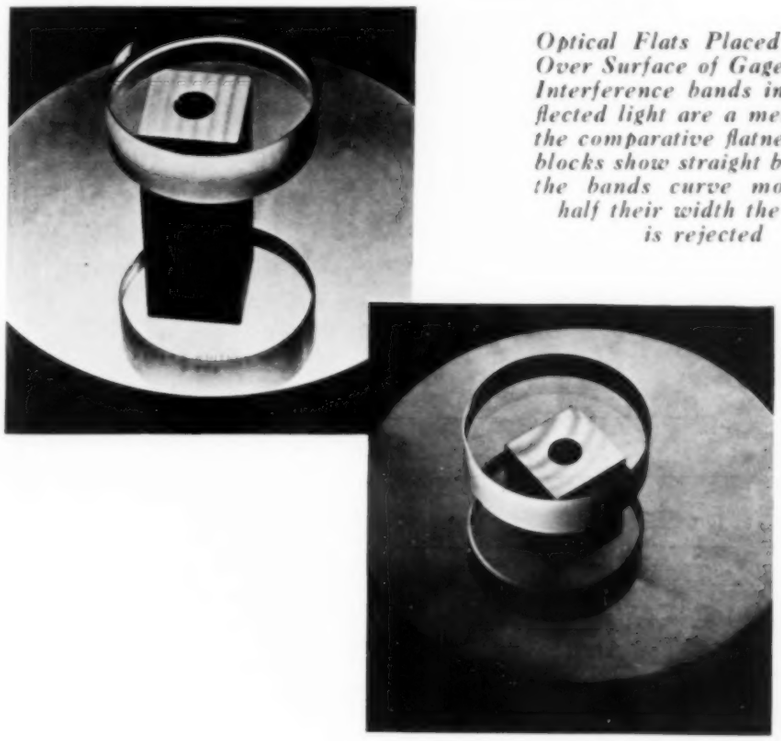
Hardening and tempering are of prime importance, as upon these operations depends the hardness of the blocks. The most modern electrically heated box-type furnaces, provided with automatic temperature control and special electric oil tempering baths, are employed for these operations.

Before seasoning, each block is ground on the faces and all four sides to remove any hardening scale and to insure the maximum efficiency from seasoning. This grinding operation is of particular importance, as it is the final operation on the sides, and when this operation is finished, the hole must be located equally from all sides. It will be recalled that the hole is of such size as to take a $\frac{1}{4}$-in. tie rod, when it is desirable to bolt a nest of blocks together. Obviously, accuracy in the location of the hole is essential.

Seasoning follows. Within the past three years Pratt & Whitney Co. has developed a new method of aging or stabilizing hardened tool steel. For many years various methods of seasoning, or of alternate immersions in lukewarm and refrigerated solutions, have been in use, and all are effective to some degree. But the newly developed seasoning treatment goes far beyond the older methods because it permits the use of higher hardening temperatures and lower draws (and thus gives the blocks a higher hardness without the defect of any growth or shrinkage which can be detected in measurements as fine as millionths of an inch).

The chart on page 74 gives the result of a test made some time ago in the Pratt & Whitney

Checking Flatness of Pratt & Whitney Hoke Gages, Using Optical Flats and Mercury Vapor Lamp



Optical Flats Placed Lightly Over Surface of Gage Blocks. Interference bands in the reflected light are a measure of the comparative flatness. Flat blocks show straight bands. If the bands curve more than half their width the block is rejected

laboratory. All blocks in this test were 4 in. long, that length being selected as one which would indicate the maximum change that might be expected in a precision gage block. Eight 4-in. blocks were so heat treated as to possess maximum hardness. Four of these superhard blocks were subjected to the Pratt & Whitney special seasoning treatment; the remaining blocks were improperly seasoned. The blocks were lapped to size and accurately measured.

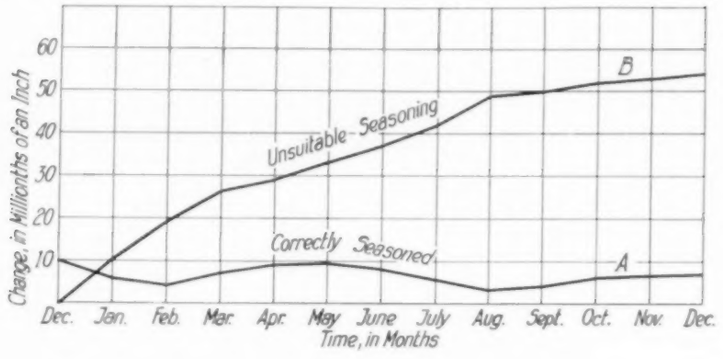
Readings of each block were made monthly. The average readings obtained from the blocks given the special seasoning treatment are shown in curve A. The readings obtained from the blocks not properly seasoned are charted in curve B. At the end of 85 weeks, the blocks given the special seasoning treatment averaged one millionth smaller than the original reading at the beginning of the test. The blocks given the improper seasoning treatment had grown 66 millionths after 70 weeks.

Every gage block must be as nearly perfect, metallurgically, as it can be made and it is necessary to inspect each block to detect any minute cracks which may have formed because of steel defects or hardening strains. Often these cannot be detected with the eye. A simple but ingenious inspection operation is therefore used.

The gage block is immersed in a bath of kerosene which contains in suspension very fine steel dust. The steel dust is attracted to the block by the residual magnetism in the block due to its previous contact with a magnetic chuck. (Sometimes an electric magnet is used when the residual magnetism is not sufficient.) Even the most minute cracks are then visible, particularly when examined under a magnifying glass, because the lines of magnetic force, interrupted by the defect, cause the steel particles to accumulate there and form a distinct line on the surface of the block.

Manufacturing operations are interrupted following this test for cracks, to give a period of natural seasoning. Blanks at this stage in process are known as Class A stock, being completed to the point of marking and of finishing the gaging surfaces accurately. They are held in stock for a period of not less than six months, and are withdrawn for completion to replenish finished stock as required.

Etching. The first operation in the finishing routine is to grind the etching band preparatory



Aging Test of 4-In. Hoke Gage Blocks Given Pratt & Whitney Special Seasoning Treatment (Line A) and Similar Blocks Improperly Seasoned. Points on curves are average measurements of four blocks

to marking. Anyone who has manufactured tools or gages from high carbon steels is familiar with the strain set up by stamping, rolling, or similar methods of marking. Often a crack originating at the corner of one of the characters is evidence of this strain. There must be no strains of this sort introduced into precision gage blocks.

To guard against any such possibility, all markings are etched on the sides. This marking includes the Pratt & Whitney name, the size of the block, and the serial number which distinguishes it from any other block of the same size. The serial number enables the user to keep a definite record of each block in use and to prevent sets being confused.

Finish Grinding is done on a Brown & Sharpe surface grinder; the most extreme care is used to keep grinding scratches as shallow as possible and to maintain the blocks equal in length. Efficiency in this practice facilitates lapping and for that reason is watched very closely. Blocks are within 0.001 in. of nominal length at this time.

Lapping. The blocks are now ready for finishing. This is divided into three separate lapping operations — rough, intermediate and final. Let us first consider the machinery.

All lapping operations are done on the machines illustrated on page 71. All are of the same type, and were designed and made by Pratt & Whitney Co. They consist of a heavy cast iron base on which a circular lap is fixed. They also carry a swinging arm from which a second circular lap is held, normally in position immediately above the lower lap. When loading, changing or unloading, the arm is swung in the outward position, leaving the top surface of the lower lap exposed.

A spider, consisting of a piece of steel in which 24 holes have been drilled, is held horizontally in position above the lap approximately one-half the thickness of the blocks to be lapped. The blocks are next placed in the holes in this spider. The diameter of these holes is larger than the distance across the corners of the blocks, so the latter are free to rotate. The spider also clears both laps.

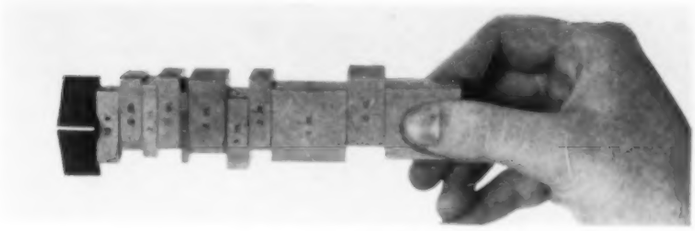
After loading, the arm carrying the upper lap is swung back into position and locked. The upper lap is lowered until it rests of its own weight on the three highest points on the 24 blocks which are to be lapped. Since machining up to the point of lapping is done individually, seldom, if ever, do all 24 blocks actually touch both laps at the start of the rough lapping operation. Furthermore, since the upper lap is free to assume a position resting on these three high points, it probably will not be parallel to the lower lap.

Lapping is done by driving the spider in a planetary motion between the stationary plates above and below. The gearing is so made that about 300,000 rotations are made before the exact path is repeated. There is thus small chance for grooves to be worn on the upper and lower flats.

As the operation progresses and additional blocks come in contact with the laps and all are lapped flat, the two gaging surfaces probably will not be parallel. Yet it is absolutely essential as the blocks approach size that they be parallel as well as flat, and to accomplish this a system of interchanging blocks in the spider has been worked out. This system places some of the longer blocks into the positions formerly held by the shorter blocks, and vice versa. When lapping is started again there will be some blocks

free from the upper lap, but these will contact, one after another, as the taller blocks are reduced.

Several methods of interchange are in use, one after another, and the blocks as they leave the rough lapping operation are very close to the same size and the surfaces are parallel. The edges are stoned after the rough lapping operation to remove any burrs or rough edges which might have been overlooked in the previous operations or which might have occurred in the rough lapping, and the blocks are ready for the final lapping operations.



When Surfaces Flat Enough Are Wrung Together the Two Parts Approach Within the Range of Atomic Forces and Hold One to the Other

The second or intermediate lapping operation closely resembles the rough lapping. But very little and the finest grade of abrasive is used. Positions are interchanged in the spider periodically as no error in parallelism may be permitted to creep in.

Practically no abrasive (except that which has been worked into the surfaces of the laps) and but a little lubricant is used in final lapping, to reduce the last few millionths. Extreme care is exercised to maintain a high finish. The blocks are checked at intervals of 10 to 20 rotations as they approach size, and places are interchanged in the spider. Sufficient time is allowed at each measurement for the blocks to come to the standard temperature of 68 F.

Inspection. Each block is measured by the operator in charge of lapping before the machine set-up is broken; then it is given a second and final check in the Inspection Department.

All blocks are carefully cleaned and remain in a pan of kerosene for several hours to insure that all are at the same temperature. A master block, the size of which is definitely known within a millionth of an inch, is placed in the same bath so that it may be at exactly the same temperature as the blocks to be checked.

The instrument used for the final inspection for size was designed and built especially for this work at the Pratt & Whitney plant, and is similar to a machine used for the same purpose at the National Physical Laboratory, Teddington, England. It is known as a "millionth comparator." To be used successfully it requires an accurate set of master blocks.

Suppose a lot of 0.1009-in. blocks is coming through. The master block, 0.1009 in. in size, is placed between two anvils of the comparator. All oil is carefully worked out so that the anvils are in contact with the surfaces of the block. A small mirror is mounted at the back of the movable head anvil, this mirror tilting as the anvil is moved. The shadow of a pointer is projected onto this mirror and reflected by it to a second and stationary mirror, and from that to a scale conveniently mounted. The reflection of the pointer acts as a lever beam of light and magnifies the motion of the head anvil until five millionths of an inch appear as one-eighth inch on the scale. When the master block previously mentioned is between the anvils the scale is moved so the pointer appears to rest exactly on zero. Then the master block is taken out, and one of the blocks to be measured put in its place. If it is exactly the same size, the pointer again rests on zero. An overage or deficiency of two millionths is easily detected. Several readings are taken in various parts of each block which give positive check against error in parallelism.

The final check before gages are sent to stock is an inspection against scratches or surface defects, and a check for flatness. Under a Cooper-Hewitt light even the smallest of surface defects is plainly visible. Blocks showing any such surface defects or scratches are rejected.

Test for flatness is made with an optical flat, which is merely a round plate of glass with flat surfaces ground on it. The flat is laid on the surface of the blocks under the Cooper-Hewitt

Making up a Set of Gage Blocks by Drawing Appropriate Blocks From Storage Safe

light, and is separated by a thin wedge-shaped film of air. Light reflections between these contiguous flat surfaces, metal and glass, respectively, cause interference bands, alternately light and dark. These interference fringes or bands are very clear and distinct and may be easily photographed, as shown on page 73. If they are perfectly straight, the surface of the block is flat. If they curve or are irregular the surface of the block is out of flat. Permissible curvature must in no case amount to more than one-half band, which translated equals five millionths of an inch.

Storage. It is necessary that the blocks be maintained in this perfect condition until shipment and a safe is provided for holding the finished blocks.

The blocks are carefully greased with a heavy non-acidic compound selected by our laboratory after careful testing. The surfaces of the blocks do not come in contact with each other when stored in the safe, so that pitting, sweating, and corrosion are avoided. It is interesting to note at this point that not a single block which has been given the Pratt & Whitney special seasoning treatment has changed size an amount which is measurable in millionths. In other words they are permanently stable and will retain their size indefinitely except for normal wear.

Constant Temperature Workshop. The condition of the rooms in which the final lapping and inspection are done is of considerable interest. These rooms are accurately maintained at 68°F. at all times. This is highly essential, as a slight difference in temperature is sufficient to cause errors in measurements greater than the permissible tolerance. Humidity is maintained just as accurately as the temperature. To guard against the possibility of a rise in temperature, all motors for driving lapping machines are located outside of the constant temperature rooms, and a flexible shaft through the wall is the driving means.

The study of the manufacture of Hoke precision gage blocks at this time is interesting, particularly in view of the final result and the improvement which can be noted. The blocks are harder than any that have been produced heretofore. They approach absolute stability, an accomplishment which has been sought for years but never before attained. This does not mean, of course, that the blocks have a zero coefficient of expansion with change of temperature, but it does mean that whenever the blocks are measured at 68°F. they will be within one millionth of an inch of their length when they left the Pratt & Whitney constant temperature room. Likewise it is not necessary to build a constant temperature room in the shop before using them, for the blocks are of steel and their coefficient of expansion is very close to that of the snap gages or the other metal whose size they are verifying. Consequently temperature will have an equivalent action on each.

notes on construction of . . .

Pickling Tanks

BY J. C. WEAVER

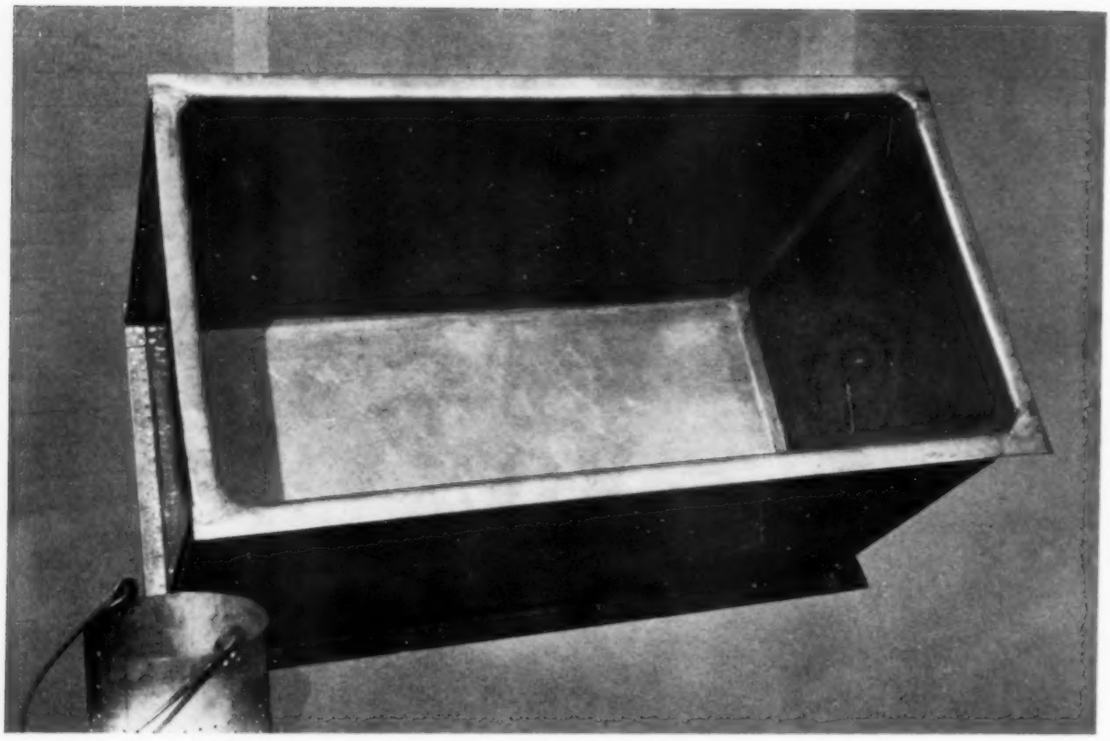
MANY STYLES and types of pickling tanks are available for use in the pickle room; therefore it is improper to make definite recommendations unless a specific problem is submitted. An article such as this should be limited to the discussion of various possibilities for choice, leaving the final decision to the reader. Tanks are subjected to two types of destruction: (*a*) chemical corrosion and disintegration, and (*b*) mechanical destruction and wear. The problem is to select the material which will best withstand both types.

Wood tanks are probably the most commonly used for general pickling practice since they are effective and economical. They can be used from one to six years and have an average life of 12 to 18 months. The advantages and disadvantages of the different kinds of woods and types of construction should consequently be discussed.

Cypress, long leaf yellow pine, and douglas fir are the most popular lumbers. Cypress is probably a little superior to other woods and is used in the construction of small tanks with walls 4-in. thick. However, it is high in price and very scarce in longer lengths and thicker timbers for large tanks. Whether or not cypress is worth its additional cost is a question that apparently has never been satisfactorily settled, but it is certainly true that most tank manufacturers carry a greater stock of other woods and can make prompter delivery in other woods than cypress.

If we eliminate cypress (either for its high cost or scarceness, particularly in larger sizes) one can then consider long leaf yellow pine and douglas fir. These are used in 5 to 12-in. thicknesses. The first mentioned has been the generally accepted pickling tank material, at least until recently. Heart lumber, free from knots, is used. Long leaf yellow pine is a good wood, but there is so little difference in the general appearance of this and other species of pine, which are not so good, that only an expert can be sure that long leaf yellow is being delivered. Good pine is rather scarce. If it has been "turpentined" it is not desirable for pickling tanks.

Douglas fir (more properly "douglas spruce," although it is commonly known in the lumber trade as red fir or Oregon pine) costs about the same as yellow pine and at the same time has a greater resistance to the corrosive action of acids. There are several reasons which lead to the belief that douglas fir is superior to long leaf yellow pine. It is more dense than the pine — that is, its cellulose con-



Monel Metal Sheets Should Be Flanged and Riveted on Outside and All Inner Corners Filled With a Thick Wedge of Lead, Placed by Welding

tent is greater per unit of volume. This means that it is not so porous or so open grained and it naturally follows that liquids will not be able to permeate the wood so quickly. Douglas fir is also less soluble in acid solutions than long leaf yellow pine. Here again the denser structure is responsible; in addition, douglas fir contains more acid-resisting chemicals; it has more oils, gums, and resin deposits which, one might say, make a protective coating around the wood fibers and keep the acid or other liquors which might be in the tank from tearing down the structure of the wood. While an ordinary wood tank might suffice for moderate requirements, douglas fir will probably give longer service at a price no higher than long leaf yellow pine and much lower than cypress.

The life of a pickling tank is of course dependent on its inherent qualities as well as the kind of treatment it will receive. If the tank is well constructed and made of properly seasoned timber the user cannot expect a reasonable length of life unless it is cared for properly. Tanks should be purchased from fabricators doing sufficient business to justify them to carry a stock of well-aged lumber, for if a tank is made of green wood it will shrink during shipment, erection or use. Needless to say, cracks will waste solution, and a leaky tank is expensive no matter how cheaply it was bought.

It is not a good policy to purchase tanks of green wood with the idea that they can stand around useless and empty until they have seasoned. As the wood dries it will shrink and before the tank can be put in use the rods would necessarily have to be tightened to bring the timbers together. It is probable that meanwhile the timbers have warped; it is then impossible to hold the tank walls together so that the joints will be tight. If the timber is seasoned before the tank is built, all warpage which might have occurred during the course of time would necessarily be planed off, and smooth, square, level joints (so necessary for water-tight construction) would be the end product.

Many tank builders construct their tanks with splined joints, the theory being that this method will make the tank more surely watertight. However, if a tank is properly designed and built, splined joints are unnecessary; in fact, it is better not to have them. Practically all wood tanks will leak occasionally and if the joints are splined it is very difficult to find the actual weak spot, as the solution will follow the spline and run out at the end of the timber.

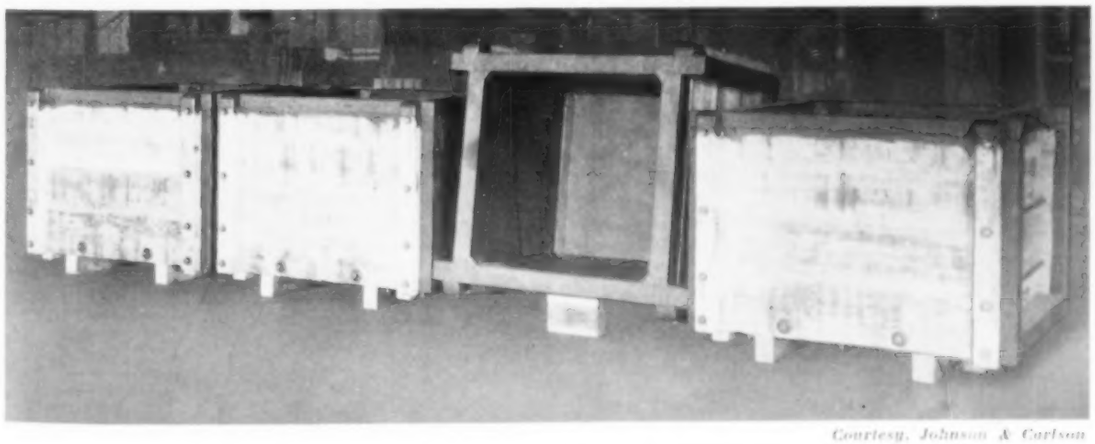
Wooden tanks may be either rectilinear, bolted with acidproof metal rods, or oval (barrel type) tightened by means of hoop-like rods which can be drawn up at regular intervals. Good rods are important since they are subject to overstressing and localized corrosion. They should be made of rolled bronze with a tensile strength at least as great as steel. Copper-tin or copper-nickel bronzes are generally superior in corrosion resistance to those containing zinc or aluminum. Bolts are also of bronze with countersunk heads packed with grease, acidproof asphalt or cement.

There are several types of drains that are adaptable to pickling tanks. Probably the most practical is one made of a lead flange and a tapered solid lead plug. Wooden plugs and acidproof valves are also used. However, more and more companies are coming to drainless tanks, using a syphon or water eductor for emptying them. This insures against drain troubles and gives a longer lived tank.

Generally speaking, if a wood tank can be used it is not advisable to line it. However, several types of lining are sometimes used. The most common are lead, rubber, and acid-resisting metal sheets.

Lead linings are used for sulphuric acid pickling and are satisfactory if the lining is not punctured. Ruptures, however, are often made by mechanical wear from racks, baskets or falling pieces. Acid then gets between the lining and the tank material and corrosion proceeds at an increased rate. Lead linings are used to best advantage in small, shallow tanks where there is less mechanical abuse and less likelihood of sagging and cracking due to lack of support. Also lead, unless very heavy sheet is used, is liable to crack or buckle under higher temperatures. The linings are usually $\frac{1}{8}$ to $\frac{1}{4}$ in. thick and extend over the edge of the tank and down the outside about a foot, thus eliminating the danger of acid entering at the place where the lining is joined to the tank. It is oxy-acetylene welded on.

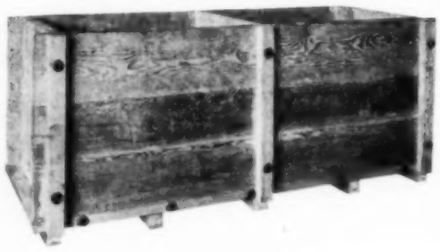
Rubber linings, such as are shown in the picture below, are used in muriatic pickling and are quite satisfactory, although the same dangers of puncturing are present as are noted above. There is less danger of cracking with soft than with hard rubber linings. Rubber lined wood or steel tanks have been in service 6 or 7 years without deterioration. Failure is more often caused by the attack of the oily film covering the surface of the pickling solution



Courtesy, Johnson & Carlson

Muriatic Acid Pickling Can Be Satisfactorily Done in Wooden Tanks Lined With Rubber. Especial care is necessary to protect the lining against accidental puncturing

than by corrosion or mechanical abuse. Rubber linings are vulcanized to steel tanks in such a way that a substantial bond is effected, and the tank will give satisfactory service if the acid temperature is held below 150° F.



Acid-resisting metal linings have proven generally unsatisfactory. Although quite practical for baskets and racks, when these metals are lining a tank the solution gets between the wood and the metal and becoming more concentrated by evaporation, it rapidly corrodes the metal.

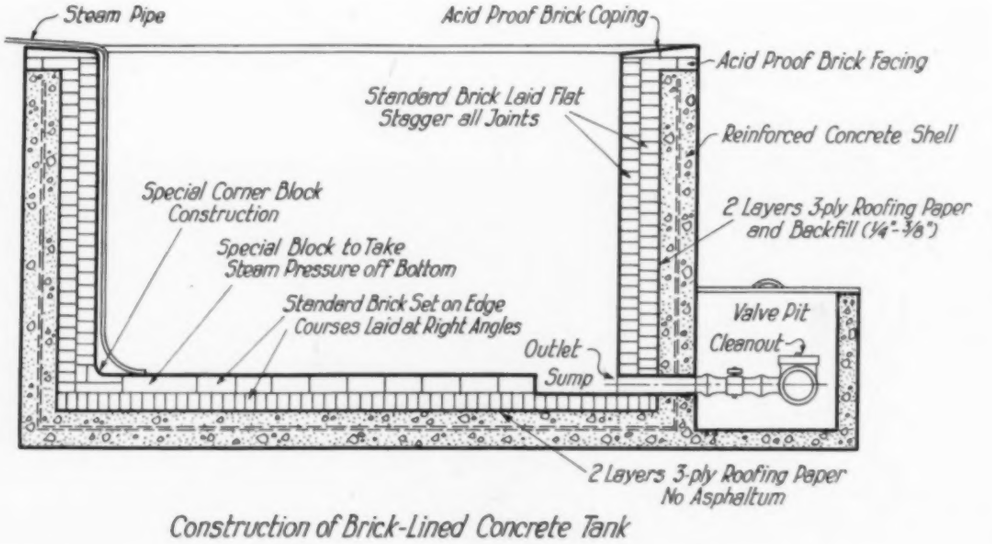
During the last few years there has been considerable interest shown in self-sustaining tanks of acid-resisting metal. International Nickel Co. and Duriron Co. have done practically all the development work in this line, promoting monel metal and durimet, respectively. Monel metal has long been considered a good acid-resisting metal, while durimet is a newer metal with great possibilities.

Monel metal cannot be welded readily by the ordinary workman, and it is therefore advisable to build the tank by flanging the sheets, riveting them and then filling the joints with lead. This construction in $\frac{3}{16}$-in. sheet is shown in the picture on page 78. Even this operation needs especial skill; ordinary "lead burners" can not do a satisfactory homogeneous job; the joint is filled layer by layer with an oxy-hydrogen flame, and the lead coating is welded on without tinning.

Durimet has an advantage in construction, as this metal can be easily welded, and the fabricating costs are, therefore, a little lower. Before deciding on an acid-resisting metal tank the prospective user should consult those who are really familiar with the performance of these metals in the class of service intended.

Several types of concrete tanks are used with more or less success. They are expensive to install but have a life of 5 to 10 years. Some companies use a straight concrete tank, making the walls 8 to 12 in. thick. These tanks, however, are not usually advisable, as acid solutions seem to deteriorate the walls to a short life.

Lead lined concrete is used by some. This, of course, gives longer life but there is still the hazard of puncturing the lead lining. Increased corrosion resistance *(Continued on page 149)*



Construction of Brick-Lined Concrete Tank

Typical Mechanical Properties of some
ALUMINUM SAND CASTING ALLOYS

Alloy	Approximate composition, per cent								Hardness			Impact	Fatigue	
	Copper	Iron	Silicon	Zinc	Magnesium	Manganese	Nickel	Aluminum (minimum)	Brinell	Shore, Magnifier Hammer	Rockwell	Izod strength ft-lb.	Endurance limit lb. per sq. in.	Endurance limit / Tensile strength ratio
12	8.0							90.0	65	21	E-75	0.70	7,500	0.34
43			5.0					92.5	40	12	E-41	0.75	6,500	0.34
47-modified			12.5					85.0	50	15	E-59	2.15	6,000	0.23
100								99.0	25	8	5-42			
106						2.0		96.0	35	12	E-25	2.80	5,500	0.28
108-72	4.0		3.0					91.0	60	20	E-70	0.35	8,500	0.40
109	12.0							85.5	75	24	E-82	0.32	10,000	0.42
112	7.5	1.2		1.5				88.0	70	23	E-79	0.35	8,500	0.39
121	12.0					1.0		84.5	75	24	E-82	0.20	10,000	0.44
122	10.0	1.2			0.2			87.0	90	28	E-90	0.28	9,500	0.37
122-70 HT	12.0				0.1			84.5	110	37	E-98	0.20		
142	4.0				1.5		2.0	90.0	85	26	E-88	0.35	8,000	0.33
142-42 HT	4.0				1.5		2.0	90.0	105	36	E-96	0.32	8,000	0.22
145	2.5	1.2		10.0				81.0	70	23	E-79	0.55	7,500	0.26
195-4 HT	4.0							93.0	65	21	E-75	2.10	6,000	0.19
195-10 HT	4.0							93.0	95	30	E-92	0.83	7,000	0.18
195-16 HT	4.0							93.0	85	26	E-88	1.85	6,000	0.17
196-6 HT	4.0				0.2			93.0	110	37	E-98	0.75	6,500	0.15

Alloy	Tension; tensile test specimen ½-in. diameter, sand cast.							Compression			Shear	
	Typical values					Minimum specification values						
	Proportional limit lb. per sq. in.	Yield point lb. per sq. in.	Ultimate strength lb. per sq. in.	Yield point / Tensile strength ratio	Elongation in 2 in. per cent	Ultimate strength lb. per sq. in.	Elongation in 2 in. per cent	Proportional limit lb. per sq. in.	Yield point lb. per sq. in.	Ultimate strength lb. per sq. in.	Shearing strength lb. per sq. in.	Shearing strength / Tensile strength ratio
12	5,000	14,000	22,000	0.64	2.0	19,000	1.5	7,000	16,000	38,000	20,000	0.91
43	3,500	9,000	19,000	0.47	4.0	17,000	3.0	3,000	9,000	25,000	15,000	0.79
47-modified	4,500	11,000	26,000	0.42	6.0	24,000	5.0	4,500	12,000	28,000	18,000	0.69
100	1,500	3,000	14,000	0.47	20.0	13,000	15.0					
106	3,000	9,000	20,000	0.45	10.0	17,000	7.5	2,500	7,000	20,000	14,000	0.70
108-72	4,000	17,000	21,000	0.81	2.0	19,000	1.5	5,000	21,500	43,000	20,000	0.95
109	7,000	18,000	24,000	0.75	1.5	21,000	1.0	6,000	23,500	45,000	20,000	0.83
112	5,000	14,000	22,000	0.64	2.0	19,000	1.0	7,000	24,000	44,000	20,000	0.91
121	8,000	20,000	22,500	0.89	1.0			6,000	26,000	49,000	21,000	0.93
122	9,000	21,000	26,000	0.81	0.5	23,000	0.0	13,000	33,500	54,000	25,500	0.98
122-70 HT	12,000		27,000		0.5	23,000	0.0	16,000	50,000	64,000	25,000	0.93
142	13,000	24,000	28,000	0.86	1.0	23,000	0.5	9,000	34,000	52,000	24,000	0.86
142-42 HT	18,000		37,000		0.5	30,000	0.0	20,000	58,000	70,000	32,000	0.86
145	7,000	22,000	29,000	0.76	4.0	25,000	2.5	6,000	34,000	50,000	22,500	0.78
195-4 HT	8,000	16,000	31,000	0.52	8.0	28,000	6.0	8,000	27,000	43,000	27,000	0.87
195-10 HT	9,000	27,000	40,000	0.68	2.0	36,000	0.0	23,000	45,500	56,000	30,000	0.75
195-16 HT	8,000	22,000	36,000	0.61	4.0	30,000	3.0	5,000	28,000	43,000	29,000	0.80
196-6 HT	14,000	40,000	43,000	0.93	2.0	34,000	0.0	18,000	56,000	64,000	34,000	0.79

HT indicates heat treated alloys.

Young's modulus of elasticity is approximately 10,000,000 lb. per sq. in. for all these alloys.

Prefix S to the Rockwell number indicates 60 kg. on ⅛-in. ball; prefix E indicates 100 kg. on ⅛-in. ball; all readings on red scale.

Olsen-McAdam impact machine of Izod or cantilever type used, specimen 10 x 10 mm. with notch 5 mm. deep having radius of 1 mm.

R.R. Moore type of rotating beam machine was used in the fatigue test; endurance limit based on 500,000,000 cycles.

Yield point is taken as the stress at which the stress-strain curve shows a departure of 0.2% from the initial modulus line produced.

Compression tests were taken on specimens having an $\frac{l}{d}$ ratio of 20; all specimens failed by lateral bending.

Single-shear strength values obtained from double-shear tests.

The data were taken from Volume II "The Aluminum Industry" McGraw-Hill Book Co., 1930.

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ALCOA ALUMINUM

ANALYSIS AND PROPERTIES OF STEELS USED BY FORD INDUSTRIES

Type of Steel	Steel Analysis: Carbon	Manganese	Chromium	Other Alloy	Silicon	Phosphorus	Sulphur	Ends Painted	Typical Parts	Properties of Typical Parts: Ultimate Tensile lb./sq. in.	Elastic Limit lb./sq. in.	Reduction in Area %	Elongation %	Brinell Hardness Note B	Type of Steel
A	0.20-0.24	0.60-0.75	0.65-0.80	V 0.12-0.15	0.10-0.15	0.03 max.	0.04 max.	Note A	Driving pinion	130,000	95,000	34	15	250	A
AX	0.18-0.22	0.65-0.75	0.80-0.95		0.10-0.20	0.03 max.	0.04 max.	White and black	Spindle bolt	115,000	88,000	38	22	175	AX
									Steering worm						
AA	0.26-0.30	0.65-0.80	0.80-1.00		0.10-0.20	0.03 max.	0.04 max.	Red and black	Front axle	135,000	130,000	65	15	270	AA
									Connecting rod	150,000	145,000	53	13	300	
									Nut for forked con. rod cap bolt	132,000	120,000	66	15.5	260	
AA select	0.28-0.32	0.65-0.80	0.80-1.00		0.10-0.20	0.03 max.	0.04 max.	T-498 all elements	Front wheel spindle	170,000	160,000	56	14	320	AA select
AAA	0.30-0.35	0.65-0.80	0.90-1.10		0.10-0.20	0.03 max.	0.04 max.	Red and white	Differential spider	170,000	150,000	45	15	C 40	AAA
									Duel high planetary gear	220,000	190,000	25	8	C 50-55	
									Hexagonal head standerd bolt	145,000	125,000	60	15.5	240	
									Water pump shaft	155,000	145,000	60	14	300	
AAAH	0.35-0.38	0.65-0.80	0.90-1.10		0.10-0.20	0.03 max.	0.04 max.	Red, white and blue	Countershaft gear	220,000	190,000	25	8	C 50-55	AAAH
AAAAL	0.38-0.42	0.65-0.80	0.90-1.10		0.10-0.20	0.03 max.	0.04 max.	Red, green and yellow	Driving gear	250,000	210,000	25	8	C 48-53	AAAAL
									Change speed gear member						
AAAA	0.42-0.47	0.70-0.90	0.85-1.10		0.10-0.20	0.03 max.	0.04 max.	Red and green	Rear axle	165,000	150,000	42	17	340-387	AAAA
									Transmission gear, low	255,000	235,000	25	10		
AAAAA	0.48-0.52	0.70-0.90	0.85-1.10		0.10-0.20	0.03 max.	0.04 max.	Blue and white	Transmission shaft assembly	255,000	235,000	25	10	C 48-55	AAAAA
Armature steel	0.05 max.	0.30 max.			0.12-0.28	0.03 max.	0.04 max.		Starter armature lamination	No physical properties specified					Armature steel
B	0.95-1.05	0.20-0.30	0.40-0.50		0.20-0.30	0.03 max.	0.04 max.		Small ball bearings						B
BB	0.95-1.05	0.20-0.30	0.90-1.10		0.20-0.30	0.03 max.	0.04 max.		Large balls and small races	300,000	280,000	2	2	C 63	BB
BBB	0.95-1.05	0.30-0.40	1.25-1.50		0.20-0.30	0.03 max.	0.04 max.	Blue and red	Large ball races						BBB
No. 1 Bessemer	0.09-0.13	0.70-0.90				0.09-0.13	0.08-0.12	Aluminum	Machine cut screws	80,000	65,000	50	20	175	No. 1 Bessemer
Special Bessemer	0.06-0.08	0.30-0.40				0.055 max.	0.10 max.		Steering shaft (Carburized)	50,000	40,000		18		Special Bessemer
C (Key)	0.30-0.40	0.50-0.80			0.10-0.20	0.05 max.	0.05 max.		Woodruff key	115,000	100,000	60	20	220	C (Key)
C (Pure iron)	0.03 max	0.12 max.		Cu optional		0.01 max.	0.04 max.		Arc wells and culverts on D.T.I.R.R.						C (Pure iron)
D	0.45-0.52	0.80-0.95	1.00-1.20		0.10-0.20	0.03 max.	0.04 max.	Green with white stripe	Rear leaf spring	200,000	180,000	50	15	380	D
DD	0.48-0.52	0.80-0.95	1.00-1.20		0.10-0.20	0.03 max.	0.04 max.	Green	Front leaf spring	210,000	190,000	50	14	420	DD
Die block (Ajax)	0.60-0.75	0.30-0.40	3.25-3.75		0.10-0.20	0.03 max.	0.03 max.		Forging dies on production						Die block (Ajax)
Die block (Hammer)	0.47-0.55	0.50-0.60	0.60-0.75	Ni 1.50-1.75	0.10-0.20	0.03 max.	0.03 max.		forging dies on production						Die block (Hammer)
E	0.27-0.35	0.70-0.90			0.07-0.15	0.04 max.	0.05 max.	Red	Radius rod yoke	85,000	60,000	60	27	165	E
									Drive shaft	110,000	92,000	38	10	250	
EE	0.35-0.40	0.70-0.90			0.07-0.15	0.03 max.	0.05 max.	Yellow	Crank shaft	140,000	130,000	51	15	350	EE
EEE	0.40-0.45	0.70-0.90			0.07-0.15	0.03 max.	0.05 max.	Red and yellow	Rear axle housing tube	95,000	69,000		21	180	EEE
EEE select	0.38-0.42	0.70-0.90			0.07-0.15	0.03 max.	0.05 max.		Camshaft	255,000	245,000	6	2	525	EEE select
Electric	0.05 max.	0.30 max.			0.90-1.20	0.03 max.	0.03 max.		Generator armature lamination	No physical properties specified					Electric
G	0.08-0.15	0.30-0.45			0.07-0.15	0.03 max.	0.05 max.	Black	Rivets, bolts and screws	54,000	34,000	68	38	115	G
GG	0.13-0.20	0.30-0.45			0.07-0.15	0.04 max.	0.05 max.	Black	Brake shoe link	82,000	77,000	67	15	170	GG
H	0.27-0.37	0.45-0.60			0.07-0.15	0.04 max.	0.05 max.	Blue	Coupling shaft housing end	80,000	55,000	60	30	160	H
L	0.23-0.30	0.35-0.50				0.04 max.	0.05 max.		Frame member	73,000	48,000	32		135	L
L.C.O.H.	0.08-0.15	0.35-0.50				0.04 max.	0.05 max.	Black with yellow stripe	Body sheets	65,000	45,000	45	50	130	L.C.O.H.
N	0.10-0.15	0.25-0.40	0.25-0.35		0.10-0.20	0.03 max.	0.04 max.	Green and black	Piston pin						N
Rustless 18% Cr	0.05-0.10	0.40-0.45	16.0-18.0		0.50 max.	0.04 max.	0.05 max.		Hub shell cap	75,000	52,000		27	B 83	Rustless 18% Cr
Rustless 18% Cr 8% Ni	0.05-0.10	0.30-0.45	16.0-18.0	Ni 7.0-9.0	0.15-0.30	0.04 max.	0.05 max.		Radiator shell	90,000	42,000		53	B 74	Rustless 18% Cr-8% Ni
S	0.60-0.70	0.70-0.85			0.15-0.20	0.03 max.	0.04 max.		Valve springs	232,000	197,000		4.5	C 42	S
SS	0.80-0.95	0.30-0.45			0.10-0.20	0.03 max.	0.04 max.	Blue and yellow	Clutch springs	242,000	205,000		2.0	C 50	SS
Music wire	Similar to S or SS								Door lock spring	308,000	270,000		6.3		Music wire
Free cutting	0.20-0.30	0.70-1.00				0.06 max.	0.10-0.15		Shock absorber wing shaft						Free cutting
V	0.35-0.45	0.25-0.40	1.85-2.50		3.60-4.20	0.03 max.	0.04 max.		Valves	70,000	50,000	40	25	275	V

Note A - White if on low side of analysis and white with green stripe if on high side.

Note B - B and C represent numbers on corresponding Rockwell scale.

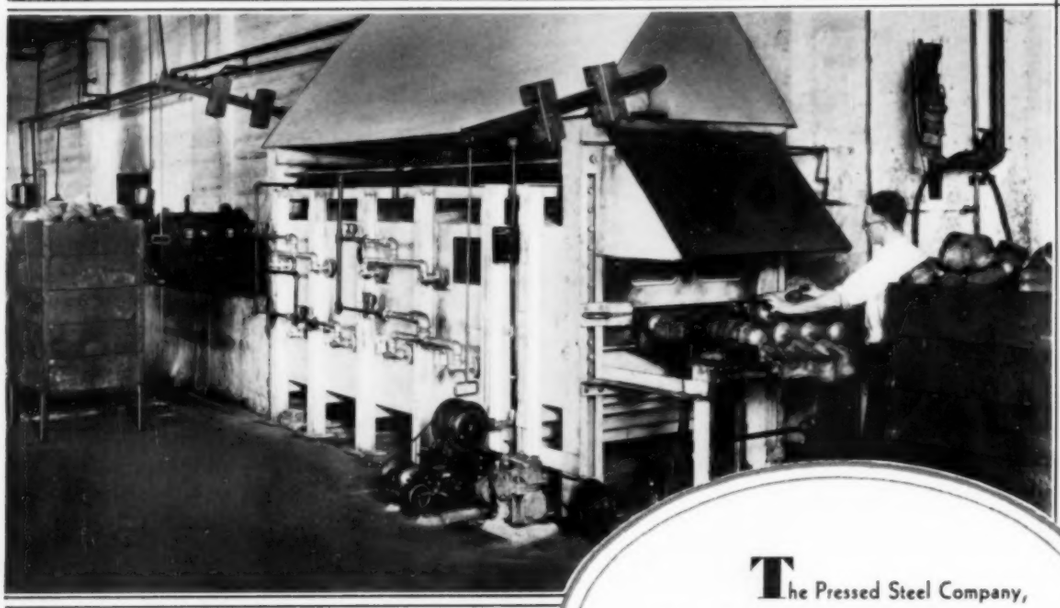
Information furnished by J. L. McCloud and G. B. Hanson of Ford Motor Co.

SC CONTINUOUS ANNEALING FURNACE

CUTS PRODUCTION COST

« « « « IMPROVES PRODUCT

FOR THE PRESSED STEEL COMPANY · WILKES-BARRE, PA.



Surface Combustion Continuous Annealing Furnace at The Pressed Steel Company, Wilkes-Barre, Pa.

The Pressed Steel Company, Wilkes-Barre, Pa., have effected unusual savings in production costs with a Surface Combustion continuous annealing furnace. Stampings, weighing up to three lbs. each, are annealed at the rate of 1000 lbs. an hour, at a temperature of 1500° F. . . . "We have eliminated all pickling, with such expenses as acids, tanks, coal to fire steam boiler, and four men," writes J. H. MacVeigh. "We are obtaining a very much better product which is uniform and which enables us to get out more production and less breakage."

›› SUBSIDIARY OF HENRY L. DOHERTY & COMPANY ‹‹

Surface Combustion

Surface Combustion Corporation, Toledo, Ohio – Sales & Engineering Service in Principal Cities

Correspondence

and Foreign Letters

International Cooperation in Air Craft Materials

INTERNATIONAL Air Safety Congress held its first meeting in Paris last December. Its object was to consider subjects and researches on safety in the air, and the means of making safety more certain. It was a happy thought to place this vital subject, which is truly international in scope, above purely national boundaries, and this manifestation of world-wide cooperation met with great success.

Among sundry problems examined the question of the safety of materials took up several meetings during which 40 papers were read and discussed. These papers reviewed all the different phases of the aircraft materials problem and they formed a comprehensive survey which will be used as a starting point in the future.

The following subjects were studied by the recent Congress:

1. Light aluminum alloys; ultra-light magnesium alloys; special chromium steels, nickel steels; nickel-chromium steels; chromium-molybdenum steels; steels for cables and stay-wires, magnets and valves; and all materials employed for aircraft and engine construction.

2. Corrosion of metals and means to combat it; heat treatment; cementation and nitriding processes; forging and welding.

3. Physical tests (hardness, impact, wear, fatigue); service fractures; the use of X-rays for material control; and the correct method of sampling for tests.

All these subjects form a very interesting symposium which will be published later. The discussions brought forth the following resolutions:

1. To unify corrosion investigations and brittleness tests.

2. To set up a uniform terminology for elasticity and plastic deformation under heat, (creep phenomena, so called.)

3. To specify steels not by trade marks but by chemical analyses.

4. To introduce into acceptance specifications provisions for sampling.

5. To classify materials in the shop and identify them by means of rapid tests (hardness, spark or appearance of fracture).

6. To study in a more thorough and extensive way the fatigue tests of materials with alternating stress (both direct and bending) and repeated impact tests.

The Congress emphasized the care taken to control and use aircraft materials. I shall write later about some of the above problems, especially of fatigue tests and of testing of brittle pieces such as foundry pig iron. For the moment I can only mention the desirability, or rather the need, of uniform definitions, tests and measurements encountered in the study and control of metals.

It is obvious that the lack of accuracy and

uniformity in the terms used to define elastic limit, fatigue limit, or strength at high temperatures, is a source of confusion, errors and waste of time. Laboratory men and construction engineers cannot avail themselves of the results of metallographic studies and therefore they may make mistakes which cause accidents. It is beyond doubt also, that the want of a rational and standard test for cast iron and for corrosion resistant metals is an impediment to the application of the remarkable improvements now being made on these materials.

In a word, the want of adequate, precise and universal definitions for properties as well as for tests, has a detrimental effect upon the development of aviation, upon the rational use of materials, and upon safety.

ALBERT PORTEVIN

Paris, France

Large Output of Steel from Cold Charge

FUEL ECONOMY is everywhere of the utmost importance in steel-making processes, especially in these times of keen price competition. It is still more essential in Italy, where the high cost of coal, most of which is imported, is not completely balanced by the low cost of labor and other items which form the total cost of production.

Very important savings have been obtained recently by the Terni steel works with a new type of open-hearth furnace designed by Mr. Fiorelli.

The first of these new furnaces was erected in 1926. Because of the good results obtained, other furnaces of the same design have been built in the Terni and in other steel works. Today eight such furnaces of varying capacities are working regularly and all have confirmed the good results of the first.

In the Terni furnace the air is blown by fans through two uptake flues placed on both sides of the gas flue and a special chamber is provided where gas and air are completely mixed before entering the hearth. The gas and air ports are so arranged that the velocity of the flame, its inclination, and the conditions of combustion can be easily regulated. This regulation is assisted by proper use of the air fans. Flame conditions are changed appropriately during the different periods of the melting and refining processes.

In order to give a general idea of the results obtained I may say that a certain 40-ton furnace, which before being altered to the new design used to make 450 heats in one campaign before general repairs would be needed, during which time 16,000 tons of steel would be produced, now makes regularly more than 1,000 heats per campaign with a total steel output of 45,000 tons. The hearth of this furnace is 11x28 ft. The cold charge includes about 85% of ordinary steel scrap and about 15% solid pig iron. During the series of heats above mentioned only small repairs were made to the front and back walls and to the roof; the air and gas ports were not repaired.

The fuel consumption is well below 20% of the steel output. Water cooling is completely eliminated. Also the consumption of refractory bottom was greatly decreased after rebuilding the furnace.

Another 50-ton furnace, of the same new design with the same solid charge, gives a daily output of more than 200 tons of steel, with a coal consumption slightly below 20%.

Three smaller furnaces corresponding to the normal 30-ton size, installed in the Oreglia steel works, have given equally good results, each one producing more than 180 tons daily from a solid charge including 86% ordinary steel scrap and 14% pig iron. The fuel consumption of these smaller furnaces likewise is less than 20% of the steel output.

The new medium sized Terni furnaces, when melting a cold charge, generally produce between 53 and 57 lb. of steel hourly per sq.ft. of hearth, while for ordinary open-hearth fur-

naces it seldom goes above 48 lb. The output per hour and per unit of hearth of the new Terni furnaces of medium size, working a cold charge, is not far below that of large open-hearth furnaces working a molten charge, which is generally considered to average between 60 and 62 lb. of steel per sq.ft. of hearth.

Other furnaces of the new Terni design are now under erection in steel works of different European countries.

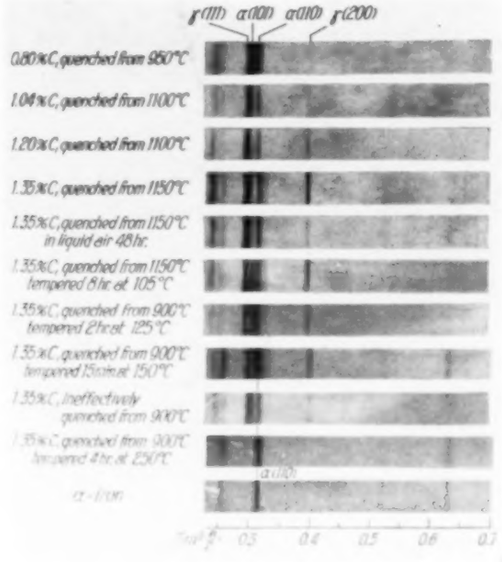
FEDERICO GIOLITTI

Turin, Italy

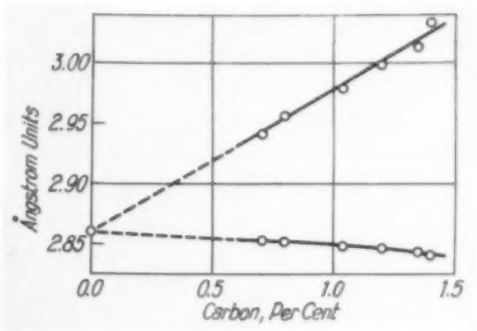
X-Ray Studies on Quenched Steels

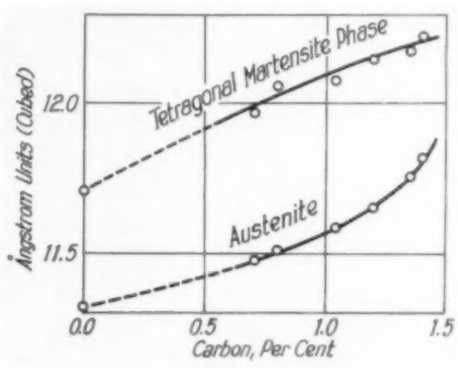
ABOUT five years ago the American scientists Fink and Campbell (and independently of them, the Russians Seljakow, Kurdumoff and Goodtzoow) made the discovery that quenched carbon steels contain a tetragonal phase which has a structure not very different from that of α-iron. This statement was received with great interest and has since been investigated by a number of scientists in different parts of the world. Kurdumoff and his collaborators have been specially successful in determining the properties of this important steel constituent.

The phase may be considered a solid solution of carbon in α-iron, the distortion of the lattice of the metal evidently being due to the presence of carbon atoms. The axial ratio increases from about 1.03 at 0.8% carbon to 1.06 to 1.07 at 1.6% carbon. Kurdumoff has shown in a diagram how the lattice dimensions change with the carbon content. When the steel is tem-


γ(111) α(100) α(110) γ(200)
0.80% C, quenched from 950°C
1.04% C, quenched from 1100°C
1.20% C, quenched from 1100°C
1.35% C, quenched from 1150°C
1.35% C, quenched from 1150°C in liquid air 48 hr.
1.35% C, quenched from 1150°C tempered 6 hr. at 105°C
1.35% C, quenched from 900°C tempered 2 hr. at 125°C
1.35% C, quenched from 900°C tempered 15 min. at 150°C
1.35% C, ineffectively quenched from 900°C
1.35% C, quenched from 900°C tempered 4 hr. at 250°C
α(110)
α-(100)
0.3 0.4 0.5 0.6 0.7

Diffraction Spectrograms of Quenched Carbon Steels, Powder Method, By E. Ohman





Upper Diagram Indicates the Relationship of Lattice Dimensions and Carbon Content of the Tetragonal Martensite Phase. Lower diagram is the volume per lattice point of the tetragonal martensite phase and volume per iron atom of austenite, as it varies with carbon content

pered at 100 to 150° C. the axial ratio decreases continuously, finally attaining the value of 1 as the lattice dimensions become exactly those of pure α-iron. The tempering evidently causes the tetragonal phase to precipitate its carbon content, forming a mixture of cementite and α-iron.

Einar Öhman of the University of Stockholm has recently confirmed these results, using the Fe-K radiation and the focussing camera constructed by G. Phragmén, which gives a higher dispersion than the cameras generally used. His diffraction diagrams, some of which are reproduced herewith, show how the X-ray patterns of quenched steel change with the carbon content and heat treatment. The variation of lattice dimensions of the tetragonal phase is shown in the diagram. The curves obtained agree perfectly with those secured by Kurdumoff.

Another curve shows how the volume per iron atom of austenite retained in the quenched specimens grows with increasing carbon content and also how the calculated volume per lattice point of the body-centered tetragonal martensite phase increases with the carbon concentration. As the interstices of the body-centered lattice are much smaller than those of the close-packed cubic γ-iron lattice, it might be expected that the volume curve of the tetragonal phase should rise more steeply than that of austenite, provided both solid solutions are of the same kind. As this is contrary to what the diagram shows, it may be taken as a sign that the tetragonal phase is not an additive product of the same kind as austenite. Nor can it be formed by a simple substitution, for then because of the relative smallness of the carbon atoms the lattice dimensions would diminish with increasing carbon content.

Öhman has, however, recently tested a third possibility, that iron atoms are replaced by groups of two carbon atoms in the solid solution of carbon in α-iron. This assumption seems in fact to be the only one which is compatible with the experimentally-determined density values of quenched steels. If all the axes of the C_2-groups in the lattice are assumed to be oriented alike, a substitution of this kind also naturally explains the tetragonal symmetry of the solid solution of carbon in α-iron.

ARNE WESTGREN

Stockholm, Sweden.

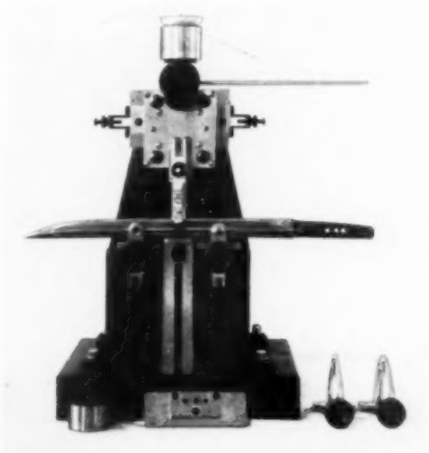
Sharpness Tests for Different Razor Blades

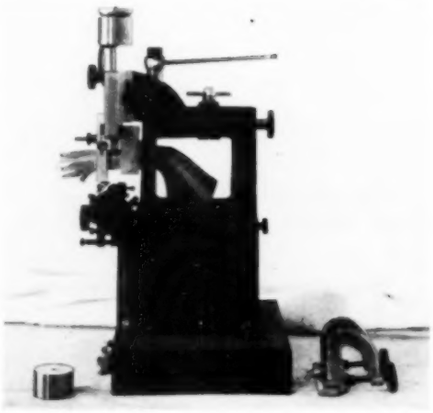
FOUR years ago the present writer constructed and announced a new instrument for testing quantitatively the sharpness of cutlery in the *Journal* of the Iron and Steel Institute. This instrument, manufactured by Tinius Olsen, Philadelphia, is now used by many cutlery manufacturers and dealers in Japan, and has

Trade Name	Edge Angle	Sharpness					Durability
		1st	2nd	5th	10th	20th	
American							
Gillette		85.8	60.7	38.3	26.5	20.0	8.5
Clark's No. 4 (1)		94.5	77.8	59.2	40.2	26.3	14.5
Gem (1)	12°	95.7	78.8	59.8	43.5	28.5	16.5
Ever-Ready (1)		85.7	69.8	50.8	36.7	23.3	14.5
German							
Baron	15.5°	78.3	65.7	51.2	36.8	29.0	27.0
Jahenckels	21.5°	97.8	77.5	46.5	28.2	18.8	11.5
Smile		108.2	81.2	55.2	38.5	24.0	11.0
Alberto		101.7	81.0	50.0	31.7	23.3	9.0
Rotbart, superfine		79.5	58.3	33.7	22.7	18.8	10.0
Rotbart		79.7	52.5	30.7	25.3	19.0	8.5
Hoja Lame		55.7	40.5	25.8	17.2	13.2	9.0
Maier (1)		65.5	43.0	25.5	14.3	11.0	6.0
Japanese							
Peace	21°	89.3	61.0	42.7	26.3	15.8	8.5
Peace (1)	13°	80.7	61.5	41.3	31.2	20.5	13.0
Kikuhide		83.3	58.5	36.2	24.7	15.3	8.5
Morning		94.7	67.5	35.8	22.0	12.8	6.0
Bon		63.5	40.0	25.3	17.8	13.3	7.0
English							
Probak		86.5	68.0	42.7	25.7	17.3	8.5
Valet (1)	17°	86.7	62.5	41.8	24.8	16.5	9.0
Swedish							
Viking		68.3	46.0	31.0	24.5	19.3	12.5
Swiss							
Kama-Extra		88.7	56.8	29.3	20.7	12.5	6.5

served to advance the art of making sharp implements. Front and side views of this new instrument are shown in the accompanying photographs. The principle is very simple and is described below.

The cutting edge of a blade is brought in contact under a definite pressure with a narrow band composed of sheets of paper, about 1 cm. wide and 3 cm. thick, placed just above the edge of the blade and perpendicular to it. The sheets of paper are then moved to the right and left a definite number of times. The number of sheets cut during this standardized motion is taken as a measure of the sharpness of the implement. Since this sharpness depends on the kind of paper and on the pressure, it is always necessary to use the same paper and the same load. The length of the backward and forward motion must also be fixed conveniently at 2 cm.





The sharpness of cutlery as defined above decreases repidly as the number of cuttings increase; in fact it decreases logarithmically. The number of cuttings required to reduce the initial sharpness to half its initial value is therefore defined as the "life" or "durability" of the blade. A good blade must have a high initial sharpness combined with a great durability, both of which can be measured by the present instrument.

The present writer has recently made extensive tests of commercial safety razor blades of both home and foreign manufacture. The initial tests were made on blades just as they come from the stores, not stropped or honed. The total pressure on the blade was 1000 grams; results are shown in the table printed at the bottom of page 88.

Blades marked by (1) are single-edged, while others are double-edged. The figures in the table are all the mean of tests on three blades of each respective maker. It is interesting to note that single-edged blades have generally a greater durability than those of the double-edged ones. You will also find from the table that America and Germany are making blades of a high class which possess an initial high sharpness combined with a great durability, and that the blades made in other countries are not much inferior to those just referred to. A blade possessing a high sharpness number will give the user the sensation of a soft touch when shaving.

KOTARO HONDA

Sendai, Japan

A New View for the Future

The year 1930 is gone forever, and so are 1929, and 1928 and all the rest of them. The word has gone out to try to revive the era of

1929 by "normal spending" and by encouragement of faith and confidence in the economic structure of the immediate past. This seems obviously the wail of those who cannot change, and for the reconstruction of an economic structure that fell of its own weight.

It now seems plain that the period preceding and including 1929 will not go down in history as the great era we thought it was. It was a period of development of mechanical jimcracks and dissipation of natural resources which stimulated many kinds of trade, resulting in a stock gambling hitherto unknown. Contrary to popular opinion, it was not an era great in scientific development. It was one of application of earlier scientific thought, the first success of which created an over-stimulated enthusiasm that ran far.

History will show this as a period of mechanical development almost devoid of advances in other arts of life. Most of the things that contribute to human satisfaction have been woefully neglected. Not only have these things been neglected, but greatly subordinated by our one-sided mechanical development.

Materialism, having to do with our food, clothing and homes, did not receive its proportionate share of attention. We talked, but have done little since the day of Benjamin Franklin's stove, about temperature control, humidification, ventilation and the use of light rays in our dwellings.

From child training to and including the marriage relations, small gain in understanding has been accomplished. Social contact, including the attitude of the people towards government, is devoid of advancement. The arts of painting and music have not enjoyed increased participation. Literature of the day, apart from the new sure-fire type, is devoid of real inspiration and creation.

The way to recover from this economic chaos, brought about by one-sided over-indulgence, is not by trying to revive the dead past but by recognizing the factors that are influencing our lives and individually contributing what we can in these other pursuits and in our relations with each other, in the hope that as we move on we move nearer Utopia.

ARTHUR T. CLARAGE

Chicago Heights, Ill.

German Engineers Study Welded Joints

ONE of the most important subjects discussed at the last meeting of "Verein Deutscher Ingenieure" was the recent improvements in welding methods.

Germany is a country which is, both in a literal and in an implied sense, studded with "Forbidden" signs. The use of welding has been somewhat held back by this fact. Government authorities have now, however, given permission to use welding for structural steel work with the result that more and more welding is replacing bolts and rivets in buildings, containers, railroad cars, bridges, and smaller fabrications. Welded steel is also replacing castings for motor crank cases and similar purposes. Welding is also extensively used in the manufacture of pipe, especially in the larger dimensions such as used for lengthy pipe lines for gas.

A new method of electric welding has been introduced by M. Zack (Oxycarbon Schweissdraht G.m.b.H., Köln). An increased efficiency is claimed for this alternating current method, since it loads equally the three phases of the electrical supply. It is possible to work with two sets of electrodes simultaneously; new possibilities in regard to the execution and composition of the weld are claimed.

A new method, launched under the trade name of "Arcogen" welding, relies on a combination of acetylene and electric arc welding. It has been developed by the Griessheim Autogen A.G. and A.E.G. It claims to combine the advantages of electric and acetylene gas welding; through the use of the gas flame in front of

the arc a considerable increase in the speed of welding is also obtained. Special coated and uncoated welding rods are said to lend favorable properties to the welded joint.

Oxy-acetylene welding has also been the subject of extended investigation. The influence of different tips and of impurities in the gases, as well as the influence of varying proportions of acetylene and oxygen, has been determined. The deductions are that economical production is mainly dependent, not on the pressure of the gases, but on the speed with which the gases pass through the tip. Fastest welding is obtained with absolutely pure acetylene and oxygen. According to E. Wiss, a 2.5% of water vapor in the acetylene will reduce the speed of welding from 7 to 11%.

It has been found that the suitability of a gas for welding purposes is not indicated by its B.t.u. value but by the maximum temperature obtainable in its flame. Extensive investigations show that the best welding results are obtained with the ratio of oxygen to acetylene is between 1.0 and 1.2. With less oxygen the weld is unevenly carburized; on the other hand a surplus of oxygen in the flame causes the welded parts to absorb oxygen (as can be shown by the usual vacuum analysis.) However, except under extremely faulty working conditions when hot brittleness may occur, the strength of the weld is not decreased by a surplus of oxygen, at least not up to proportions of two to one.

The influence of nitrogen on the weld has been studied by J. Fuchs. His published reports show that considerable variations in nitrogen content occur but that nitrogen under otherwise normal conditions hardly has a detrimental influence on strength. These conclusions do not check the results of other investigators.

To increase the tensile strength above that obtainable with plain carbon steels (55,000 to 90,000 lb. per sq.in.), alloy steels with chromium, chromium-nickel, chromium-molybdenum and chromium-vanadium are being used. A tensile strength up to 105,000 lb. per sq.in. in the weld is thus obtainable. Such a high strength in the weld has, however, only been obtained through subsequent forging, annealing, and other heat treating operations on the welded parts.

In untreated welds the tensile strength is usually only about half of the strength of the alloy rod, and in endurance tests the results show even less favorable proportions. After proper treatment the tensile strength of the weld can be counted as 90% of the strength of the surrounding steel; endurance tests show about 65% of the values for forged steel of similar analysis.

Opinion is divided on the comparative advantages of coated and uncoated welding rods. Several new investigations indicate that under proper procedure the bare rods give results that are not lower in strength than those obtained with coated rods. Further investigations, under carefully controlled conditions, are necessary before a definite answer can be given.

Among the high alloy steels, the results of welding the non-rusting and non-corrosive steels used for large chemical apparatuses and similar purposes, are the most interesting. The question of intercrystalline corrosion is of deciding influence on parts whose size or dimensions preclude forging and annealing after welding. This phenomenon has been studied at Krupp's, and new alloys have been developed from their well-known Nirosta steels, that can be heated to the critical temperature range of 600 to 700° C. without showing any intercrystalline corrosion. It is, therefore, possible to weld these alloys without submitting them to subsequent treatment.

Great interest is now shown in the development of non-destructive testing methods.

E. W. Ehn

Cannstatt, Germany

These notes on the nickel industry have been prepared at the request of the Non-ferrous Data Sheet Committee of the Institute of Metals Division, American Institute of Mining and Metallurgical Engineers, and the Recommended Practice Committee of the American Society for Steel Treating. They will be included in the next edition of National Metals Handbook.

the Nickel industry

BY A. J. WADHAMS

NICKEL ores worked as sources fall into three main classes: (1) Sulphide, represented chiefly by the pyrrhotite, pentlandite and chalcopyrite ores of Connecticut, Pennsylvania, Canada, and Norway. Small quantities of ores of this type have been mined in Sweden, Italy, China, Tasmania, South Africa, Great Britain, India, California, and Missouri. (2) Oxidized ores of the garnierite type occur chiefly on the border of North Carolina and Tennessee and in the island of New Caledonia in the South Pacific. Similar ores occur in Borneo, Madagascar, Spain, Russia, Cuba, and Oregon. (3) Arsenical ores occurring in Ontario, Colorado, New Mexico, Saxony, Bohemia, and France. Other sources of nickel are small fractions in many of the copper ores, in manganese ores of the early class known as wad, and in nickeliferous iron ores, such as those of Cuba.

Smelting and Refining

International Nickel Co. Process.—In the Orford (International Nickel Co.) process, the ore is ground fine, classified, roasted in Dwight-Lloyd sintering machines, smelted in reverberatory furnaces, and then charged into converters with siliceous flux to produce a liquid slag which carries off the iron. The bessemer matte so produced is fused with sodium sulphide, or sodium sulphate (nitre cake) and coke. The product solidifies in two layers. The first layer known as "tops" contains copper and iron sulphides; the second layer known as "bottoms" contains nickel sulphide. Re-smelting these tops and bottoms progressively purifies the product. The sodium sulphide is recovered from tops in refining the copper. The copper is blown to blister in basic-lined converters and refined electrolytically. The bottoms, containing nickel sulphide and a small quantity of copper, are washed to remove the mechanically enclosed sodium salts and roasted to remove the sulphur. The oxide is reduced to metal in reverberatory furnaces and cast into anodes.

Electrolytic Process.—The electrolytic refining process for nickel has been so perfected that electrolytic nickel of high purity can be obtained in place of less pure shot and ingot nickel. The usual practice is a nickel sulphate electrolyte, purified continuously, and maintained at a high state of purity in contact with the cathode. Anodes made from roasted nickel sulphide bottoms have low iron and sulphur contents. Early producers of electrolytic nickel were V. N. Hybinette and D. H. Browne. The principles worked

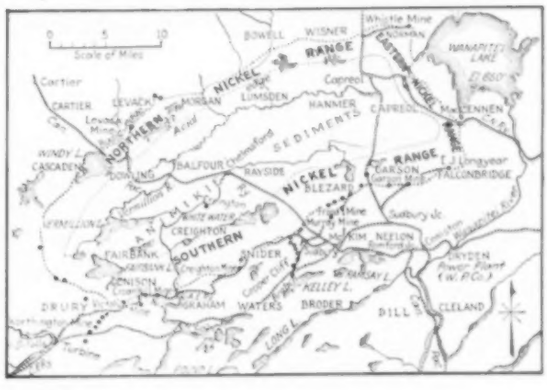
out by them are still in use, but with changes made in mechanical handling as better facilities have been developed. The present practice of refining from ore to bottoms to anodes to 99.95% nickel (plus cobalt) cathode is known as the Stanley process. The cobalt content range is 0.30 to 0.40%.

Mond Process.—The Mond Nickel Co. process depends upon the property of nickel forming a volatile compound with carbon monoxide up to about 80° C. and releasing the nickel as metal at about 200° C.

Crushed Bessemer matte is shipped to the refinery at Clydach, South Wales, where it is calcined to drive off sulphur and treated with hot dilute sulphuric acid to dissolve out the copper. The nickel oxide is reduced to metal and treated with carbon monoxide gas to form nickel carbonyl. The nickel-laden gas is then passed over pure nickel pellets at a somewhat higher temperature. The increase in temperature releases the nickel as metal which is deposited on the pellets. The regenerated carbon monoxide is used as a nickel carrier over and over again.

Refining New Caledonian Ore.—New Caledonian silicate ore (garnierite) is smelted to matte. The sulphur is supplied by adding gypsum or any alkaline sulphide to the furnace. The matte is blown to a high grade in bessemer converters, and the iron is eliminated in the slag. After roasting to drive off the sulphur, the oxide is made into a plastic with reducing materials and produced in shape of cubes or rondelles.

Grades of Nickel.—Nickel is marketed in various forms, depending upon the use intended. These forms are: (1) grains, cubes, rondelles, which are reduced from the oxide at low temperatures without fusing; (2) nickel pellets produced by decomposition of nickel carbonyl gas without fusing; (3) electrolytic cathode sheets

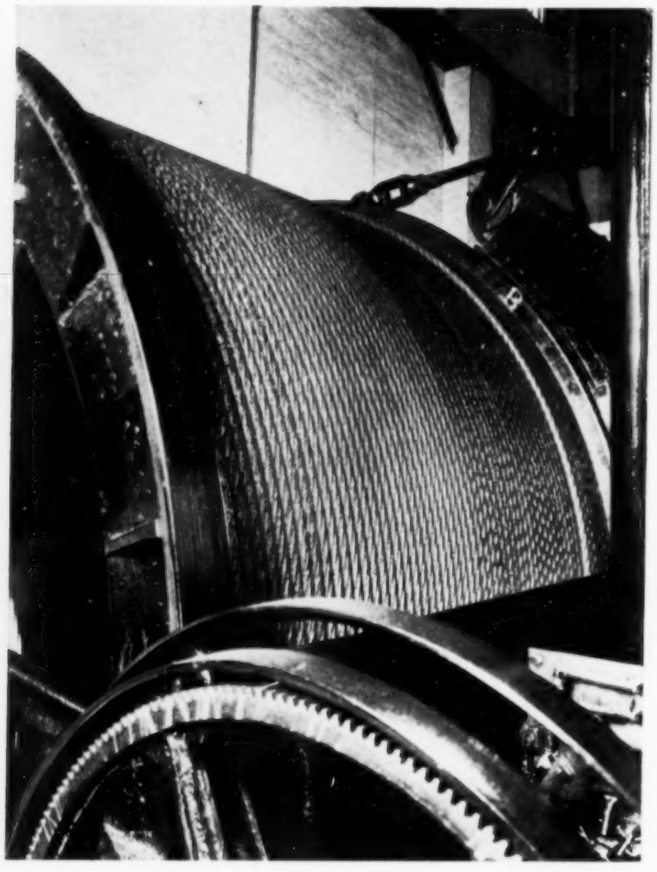


Most of the World's Nickel Comes From a Small Area near Sudbury, Ontario

by remelting electrolytic nickel which is cast into pig molds or poured into water without deoxidation; (5) malleable nickel produced by pouring into ingot molds after deoxidation. Malleable nickel is marketed in the forms of hot and cold-rolled sheets, hot-rolled and cold-drawn rods, wire, strip, and seamless tubing; (6) nickel salts; and (7) nickel oxide.

Uses in Ferrous Alloys

Nickel Steel.—Nickel steels are used for structural purposes where strength and toughness are required. Typical applications include transportation and power fields, naval and ord-



Large Hoisting and Extensive Mining Equipment and Enormous Concentrating Plants Are Necessary to Get the Ore Ready for Smelting

nance construction, and locomotive firebox plates. Because of the space and weight limitations which necessitate a material of greater strength for equal or less weight to obtain the necessary power, nickel steel boiler plate is coming into general use for marine, locomotive, and stationary boilers.

Nickel and nickel-chromium steels are used for a wide variety of forgings for structural parts subjected to high alternating stresses. Steel castings and roller bearings are also examples of nickel steel applications.

Nickel Cast Iron.—Nickel is used in gray iron to refine the grain; to reduce or eliminate chill; to obtain maximum machinable hardness; to increase wear resistance, strength, density, and resistance to corrosion and heat. Thin section castings on which the production loss is heavy through breakage due to chill are being produced without breakage by adding a small amount of nickel. Nickel-iron castings are usually free from hard spots as well as chilled edges.

Certain cast iron compositions carrying nickel have recently been developed to take advantage of their special properties. One of these containing up to 2% nickel is capable of developing over 50,000 lb. per sq.in. tensile strength. A cast iron with about 14% nickel and some copper and chromium is a good corrosion and heat resisting alloy. Another special iron with an extremely hard chilled surface contains up to 4.5% nickel and over 0.75% chromium. The chill is granular, stronger, and 150 to 250 Brinell numbers harder than that of ordinary chilled iron. Because of its toughness and resistance to wear, which is several times that of chilled iron, this alloy finds application where it is subjected to abrasion, grinding, and frictional wear.

Nickel-Chromium-Iron Alloys.—A nickel-chromium-iron alloy with a combined nickel and chromium content of 26 to 32% is a general purpose alloy of good corrosion resistance and good mechanical properties. The common composition for this alloy is 18% chromium and 8% nickel. It is referred to usually as "18 and 8 alloy" and frequently, but ambiguously, as "stainless steel." Other alloys with rather similar characteristics contain around 20% nickel and 8% chromium.

Another nickel-chromium-iron alloy with a combined nickel and chromium content of approximately 35 to 75% is essentially a heat resisting alloy. The heat resisting compositions have been in use for a longer time than the general purpose alloys and carry from 20 to 60% nickel and 8 to 30% chromium. A rather large number of compositions within these ranges are

All Illustrations by Courtesy of Engineering & Mining Journal.

commonly produced, some being better in strength at high temperatures, others in durability. A commonly used type carries 60% nickel and 15% chromium, and an important application of this alloy is resistance heating elements.

A number of modifications of both of these two general nickel-chromium-iron alloys are of some importance commercially.

Nickel-Iron Alloys.—With increasing nickel content above 25% the thermal expansivity in nickel-iron alloys decreases to relatively zero at 36% nickel. This latter patented composition, invar, is used for tape measures and other measuring devices, in watch parts, and in construction of automotive pistons. Other patented nickel-iron compositions have expansion coefficients equalling those of glass and platinum.

Nickel-iron alloys in the range of 20 to 30% nickel can be made non-magnetic by suitable heat treatment. An alloy carrying 9 to 13%

nickel with a small amount of manganese finds use as a non-magnetic cast iron. The magnetic quality of the nickel-iron alloys (permeability, temperature coefficient, and hysteresis) is sensitive in its dependence on composition, heat treatment, and cold work.

Permalloy contains about 80% nickel and has a high magnetic permeability at low field strengths. This alloy is the most important nickel-iron alloy and is used in the form of wire, strip, and a compressed brittle powder. With much the same magnetic properties, a somewhat similar alloy, except that it carries copper, known as mumetal, is a British development.

A 50% nickel-iron alloy, hipernik, has particularly high permeability and low hysteresis loss at low inductions, making it suitable for the cores of current transformers and audio-frequency transformers. By means of a special heat treatment, this same composition is given the property of a relatively constant permeability for a considerable range of flux density, and with this property is known as copernik. Still another alloy, known as "A" metal and carrying 44% nickel and a low copper content, is used in loud speaker construction, audio-frequency transformers and impedances, and rectifier filter chokes, since it characteristically gives very little distortion.

A certain range of composition of the nickel-iron-cobalt ternary system, in which the nickel and cobalt are about 45 and 25% respectively, is characterized by a constant permeability in the lower range of the magnetization curve, a small hysteresis loss at the same range, and a constricted hysteresis loop at the origin for medium flux densities.

Still another eccentric nickel-iron alloy is that known as elinvar, carrying about 36% nickel and some chromium and silicon, whose important and unusual property is a low temperature coefficient of the elastic modulus. It is used for springs and in scientific metric instruments. The elastic modulus is practically independent of temperature between 50 and 100° C.

Uses in Non-Ferrous Alloys

Monel Metal.—This is the trade marked name of a copper-nickel alloy which contains about 67% nickel, 28% copper, 2% iron, together with small amounts of carbon, manganese, and silicon, and is made directly from the copper-nickel ores of Sudbury, Ontario, by roasting the copper-nickel converter matte and reducing the resulting oxide to metal with charcoal.

The alloy is silvery white in color and its principal industrial assets are corrosion resistance, ease of fabrication by all usual methods, and wide range of mechanical properties.

Its corrosion rate is low in most corrosive media, including dry and moist atmosphere, fresh and sea water, solutions of most inorganic salts, alkalis, and acids. Some media attack it

appreciably, such as the solutions of ferric salts, sulphurous and nitric acids, and free halogens.

The alloy is quite malleable, both hot and cold, and is machinable. It finds wide application in the food, chemical, mining, building, and similar industries because of its rustless and corrosion resisting properties.

Malleable Nickel.—Malleable sheet nickel is used for dairy equipment, fish packaging equipment, hotel and restaurant kitchen equipment, and cooking utensils. Four per cent manganese-nickel is used for automobile spark plugs, pyrometer protective tubes, and all types of high temperature service. Seamless nickel tubing is widely used for condensers, refrigerating machinery, caustic evaporators, and similar equipment. Over twenty countries have struck and have in circulation coinage of pure nickel. There seems to be at present a tendency towards the general adoption of pure nickel coinage to take advantage of the better appearance.

Nickel Plating.—One of the oldest uses for nickel is nickel plating, which continues to be important aesthetically and as a preventive against the rusting of steel. Thicknesses of less than 0.0001 in. were usual, but it is now common practice to develop thicknesses of 0.0005 to 0.001 in.

The present widescale development of chromium plate has been made possible with the aid of underlying layers of nickel plate. It has been invariably found true that chromium

Burning Sulphur Out of Matte Is Important Step In Smelting

is deposited much more satisfactorily on nickel than on any other metal, and also that the chromium layer alone, as commercially applied, will not protect steel from the weather but is dependent on an intermediate thickness of nickel.

Copper-Nickel Alloys.—Nickel and copper form solid solutions in all proportions which are ductile and malleable throughout the entire range. Even in small amounts nickel decolorizes copper. Copper-nickel alloy, containing 50% nickel, is used for remelting in the manufacture of nickel-copper alloys. An alloy containing 40 to 45% nickel is marketed under a variety of trade names for pyrometer and electrical resistance wire.

Over fifty countries have in circulation coinage of copper-nickel alloys. The common composition is like the U. S. five-cent piece, which is 25% nickel.

Copper-Nickel-Zinc Alloys.—Nickel silvers (German silver or nickel brasses) comprise one of the oldest uses of nickel. Nickel silver is used as a base for silver plating—particularly spoon stock, dishes, platters, miscellaneous jewelry, and bric-a-brac. It is used for key stock, domestic plumbing fixtures, springs, electrical wire, and soda fountain equipment. Protected by a lacquer coating, it is suitable for all sorts of small ornamental hardware, architectural grill work, and casements.

Nickel Bronzes.—In bronze pressure castings, 1 to 5% nickel refines the grain and eliminates porosity. In valve bronzes, nickel improves hardness and strength at steam temperatures. It is used in high lead bearing bronzes to prevent lead segregation.

Nickel-Chromium Alloys.—The alloys of nickel and chromium, with 80% or more nickel, have two important characteristics—resistance to oxidation at high temperatures (up to about 2150° F.), and high electrical resistance. As a result this series of alloys is widely used for resistance heating elements in electric furnaces.

Nickel-Gold Alloys.—White gold carries from 14 to 19% nickel, depending on the carat, color, and hardness desired. This use absorbs about 20,000 lb. of nickel annually. It has been the practice in recent years to add a per cent or two of nickel to yellow and green golds for the purpose of hardening the gold which otherwise would be too soft for ordinary wear.

Nickel in Light Alloys.—In aluminum die casting alloys, the use of approximately 2% nickel improves the casting properties in chilled molds and gives improved color and structure. These castings are used in making automobile steering spiders, vacuum cleaner bodies, and miscellaneous hardware. Nickel is also added to special light alloy casting compositions for automotive pistons and for other applications involving relatively high temperatures.

Miscellaneous Uses of Nickel

Edison Storage Battery.—The iron-nickel hydrate Edison storage battery is universally known. It requires annually substantial amounts of nickel in metallic, oxide, and reduced form, both for the active chemical constituents of the cell and in the plating of the steel parts of which it is made.

Nickel Catalysts.—Nickel catalysts have been used chiefly in the hydrogenation of unsaturated oils, such as cotton seed, for the production of edible fats. Nickel catalysts are also used in the cracking of petroleum, desulphurization of domestic coal gas, and various types of synthesis from acetylene, carbon gases, and atmospheric nitrogen.

malleable iron by

Short Anneal . .

BY C. B. PHILLIPS

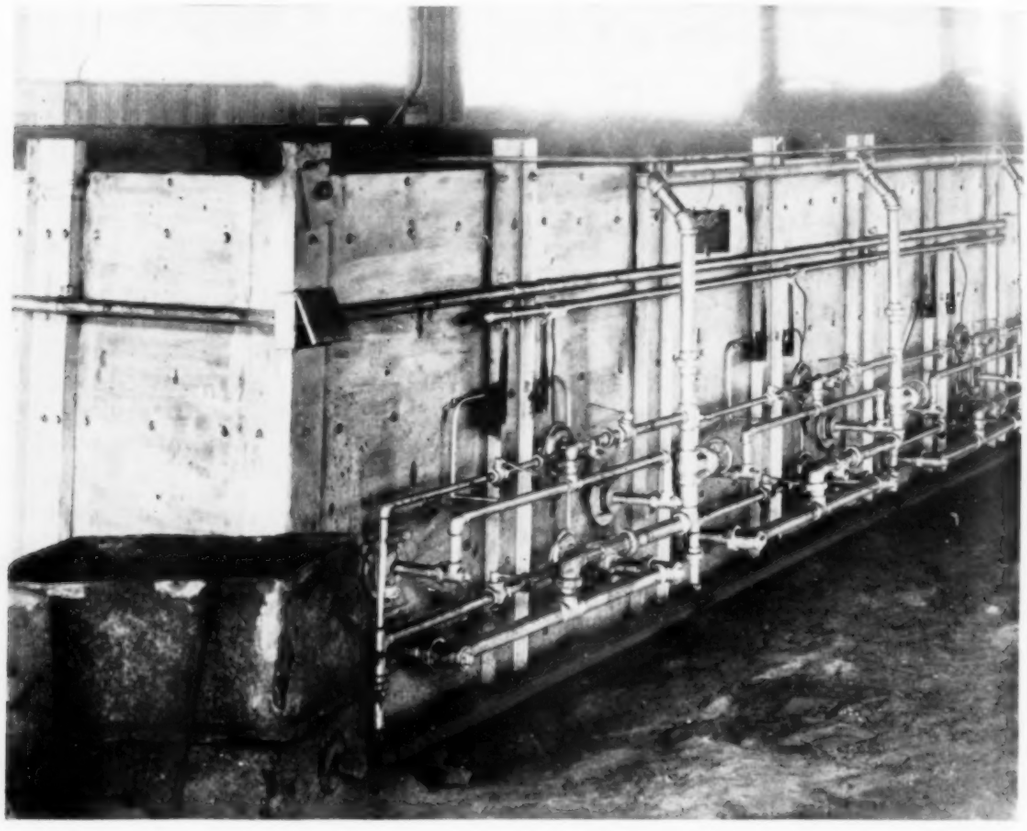
MUCH TIME, money, and thought have been given by those in the malleable iron industry to the development of the "short cycle" anneal, but the results to date have been mostly unsatisfactory, as indicated in an article in METAL PROGRESS last November. The problem of annealing within the limits of a few hours has been solved in the laboratory, but I know of no plant where this is being done on a commercial scale. The nearest approach is the practice developed by the Southern Malleable Iron Co., East St. Louis, Ill., which has succeeded in reducing the period from around 15 days to 4 days through the use of metallurgical control and correctly designed furnaces.

It is well known that the change desired includes the absorption of free cementite into solid solution in iron, and the precipitation of the absorbed carbon from the solid solution in the form of graphite or "temper carbon." The first part of this change takes place very quickly at high temperatures, on the order of 15 min. at 2,000° F., but this time lengthens as lower heats are used. For example, the time increases to 30 hr. with only about 50° drop in temperature.

On the other hand, precipitation (the second part of the change) is speeded up with a progressive decline in temperature within the limits of 1,380 and 1,290° F., the action being reversed when the swing is below the lower limit of this range. However, the higher temperatures quoted for both actions are too close to the softening point of castings, and in practical operation some compromises are necessary.

In any event, exceptionally close control of the malleableizing cycle is to be maintained. (The processes used by Southern Malleable Iron Co. are patented.) With every melt of iron several bars are taken and an analysis made on the spot to determine the heat treatment schedule; the latter is changed for every variation in the laboratory return as little as 0.05%. These test bars are kept for future reference. Castings made from each melt are kept separate and are annealed in furnaces operated on the schedule specially set up for them.

The highest temperature used in these operations ranges quite a little higher than the usual 1,650° F. Three days are allowed for the furnace and charge to come up to this heat. Successive periods of holding and declining temperatures are then employed, the speed of cooling ranging from 6 to 10° per hr. The control is so close that test bars placed in the furnace with the castings must show 0.03% of



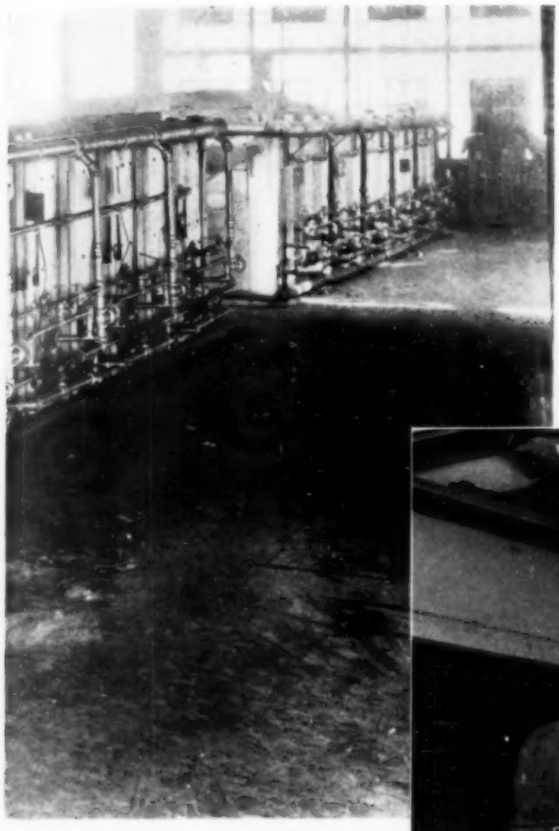
combined carbon to prove that the work has not been overannealed. Each important casting has two lugs, one for the plant record and one for the customer.

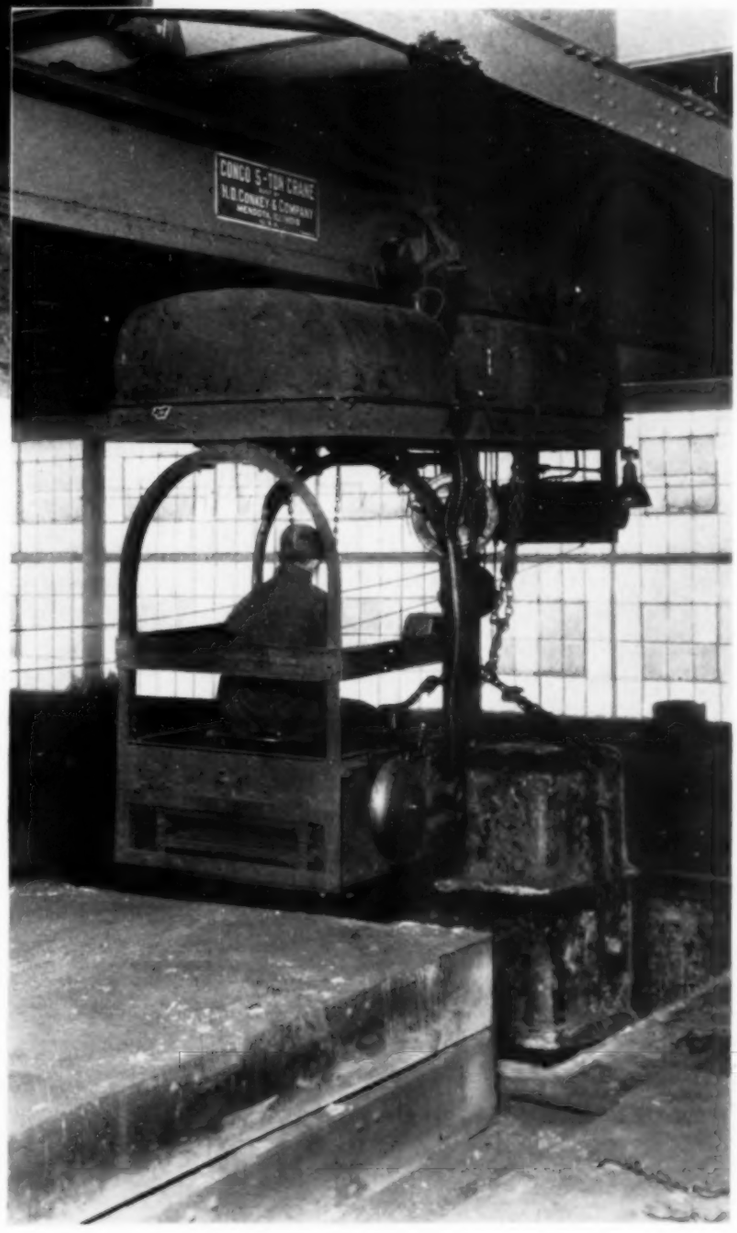
Permanent records on cards include the heat analysis, malleable schedule, temperatures taken every half hour, and percentage of combined carbon at the end.

The furnaces for this short-cycle anneal contain some unique features of design — the most interesting arising from the fact that they are loaded and unloaded from the top, the same as soaking pits in steel mills. Pit-type furnaces are seen in old-time malleable furnaces, but their construction is crude indeed compared to a modern furnace. In fact, latter-day trends have been toward "through" furnaces, cold work going in one end and pushing completed castings out the other.

There are 21 of these furnaces located in two groups, back to back. They are fired with gas. Combustion equipment was manufactured by the Surface Combustion Co., Toledo, Ohio. Formerly, some furnaces used in this plant were fired with gas and some with oil. Comparative studies have demonstrated that adequate control was difficult, if not impossible, with the oil-burning equipment, so gas burners were installed on all the new units.

Each of these furnaces is 5 ft. long, 6 ft. wide, and 8¾ ft. high. Wall and bottom construction includes 9 in. of firebrick and 12 in. of powdered insulation. The removable tops are flat steel boxes lined with insulating material 10 in. thick. As shown in the views on page 100, heat is supplied through four gas burners located in the front wall in two groups close to the opposite ends. Each group consists of a small and a large burner equipped with low pressure air-gas inspirators. When starting up the furnace or when a new charge is loaded in, all four burners are turned on to bring the temperature up to maximum in the shortest time possible. When this heat has been reached the larger burners are turned off, for the two smaller ones are sufficient to maintain the tem-





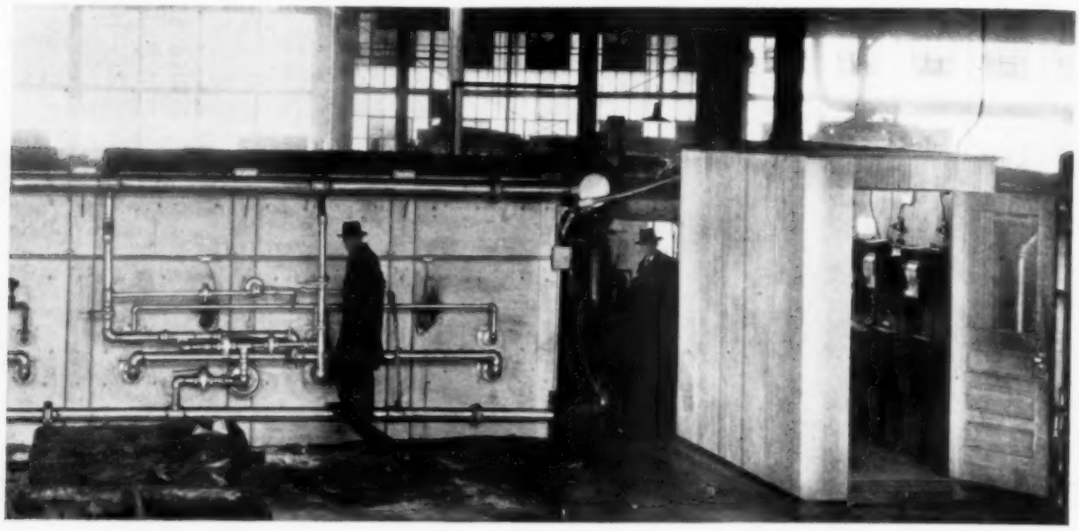
Gas Fired Malleableizing Furnaces Have Flat Movable Tops and Work Is Handled In and Out by Mono-Rail Crane

perature. Economy in time, capacity, and fuel is thus established.

The flue is built into the same wall as are the burners, with an intake about a foot above the hearth. With this arrangement the products of combustion flow over and between the stacks of pots constituting the furnace load, down on the other side, and return by way of the bottom and through the stack. This insures uniform heat distribution and maximum effectiveness. All of the furnaces are provided with recording pyrometers which are housed together in a single room.

Fourteen other furnaces of the same general design are arranged in two groups of 10 and 4. The units making up the last-mentioned group, however, are somewhat larger in floor area, each being 12 ft. long, 6 ft. wide, and 8¾ ft. high.

The plant is equipped with a monorail crane system for handling materials, which serves all of the furnaces. Castings are shaken



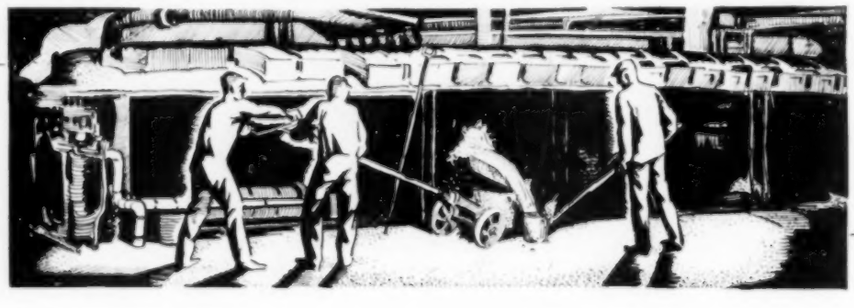
Firing System At One End of One of the Furnaces. Temporary shed housing pyrometer recording and heat control apparatus is at right

out and brought to the cleaning room in wheelbarrows, three of these being lifted by the monorail hoist at a time, a frame with chains and hooks being employed. Cleaned castings are packed in specially designed pots and charged into the furnaces with the same monorail hoists which remove and relocate the covers on the furnaces. After malleableizing, the pots are removed, castings unpacked, and taken to the finishing department with the monorail and magnet.

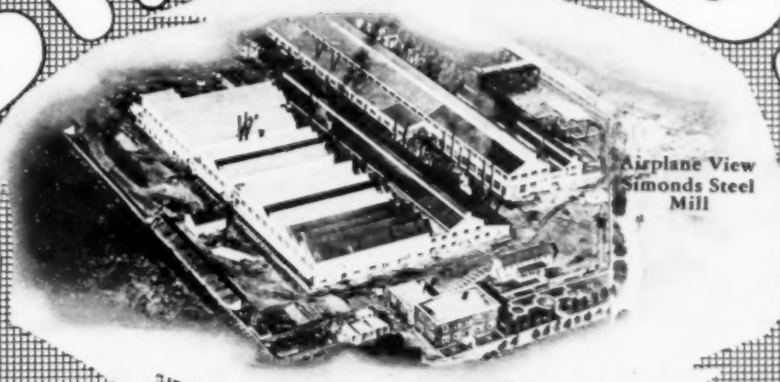
The Southern Malleable Iron Co., which makes castings primarily for the automotive, railroad, and stove industries, has developed another unique practice, consisting of duplexing the cupola with a refining furnace. A cupola discharges molten iron into a reverberatory type of furnace where it is refined and kept in a highly fluid state so that molten metal is available to the molders at all times.

The cupola is so designed that it can be drained, refilled, and started on a second heat without dropping the bottom, a careful handling of the wind aiding materially in this practice. Melted iron is poured into the reverberatory furnace, arriving there at a heat above 2,200° F., and is then superheated to about 2,840° F. and the carbon and other elements adjusted to the required analysis. A charge can be melted, tapped from the cupola to the furnace, refined, and tapped into the ladles in 100 min.

This method also controls the metal analysis, for several test pigs are cast and examined during the refining process. A desulphurizing compound is also introduced into the cupola through the tuyeres. Castings resulting from these carefully controlled operations are naturally of high quality.



SIMONDS



Airplane View
Simonds Steel
Mill

High Speed Steel **Carbon Tool Steels**

Cobalt Magnet Steel

Tungsten Magnet Steel

Chromium Magnet Steel

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Special Grades for Electric Purposes

Low expansivity (minimum coefficient) types

Stainless Steel **Stainless Iron**

Sheets **Bars**

Cold Rolled Strip

SIMONDS STEEL MILL
SIMONDS SAW & STEEL Co.
LOCKPORT, N. Y.

The Alloy 85—5—5—5

These notes were prepared by J. W. Bolton, metallurgist, the Lunkenheimer Co., Cincinnati, F. L. Wolf, technical superintendent Ohio Brass Co., Mansfield, Ohio, and William Romanoff, technical superintendent H. Kramer & Co., Chicago, Data Sheet Committee of the Institute of Metals and the Recommended Practice Committee, A.S.S.T. They will be included in the next edition of National Metals Handbook.

THE alloy known as 85-5-5-5 is a copper base alloy composed of 85% copper, and 5% each of tin, zinc, and lead, plus or minus certain tolerances. Years ago it was called ounce metal, because the usual mixture was one ounce each of tin, zinc, and lead to each pound of copper —which roughly approximates 85-5-5-5. Today this alloy is widely known as "eighty-five three fives."

The alloy is used for general utility purposes where reasonable strength and noncorrosive properties are demanded. It is rather widely used in the manufacture of many pressure castings, in some cases for bearings, and for miscellaneous engineering applications.

85-5-5-5 alloy is one of the most widely used nonferrous sand cast alloys. It is estimated that about 60,000,000 lb. of this alloy was cast in the United States in 1929. The alloy possesses the attributes of fairly low cost, good physical properties, good casting properties, and easy machinability.

The microstructure of the matrix of this alloy closely resembles that of the binary alloy of copper with 7 or 8% tin. The coring formation, characteristic in sand cast alloys of this type, is well pronounced. As a rule, delta eutectoid is not found, or occurs only in small amounts. The characteristic cored matrix contains many small globular particles of lead. Lead is insoluble and usually is found in the dendritic fillings. *(Cont. on page 106)*

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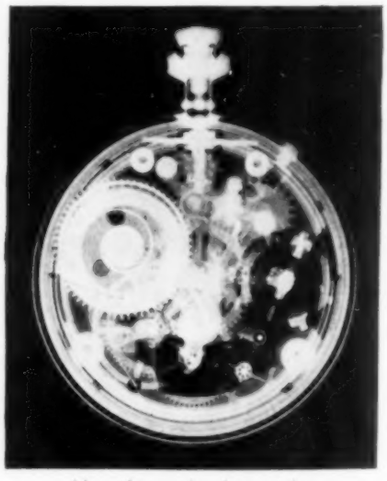

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The telephone has become such an every-day, matter-of-fact convenience—like running water and electricity—that it is natural to take it for granted. It is well to pause occasionally and consider the nation-wide organization of men, money, and materials that makes this vital service possible, and at such low cost.

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No other money that you spend can bring you more actual value.

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There are a number of specifications for this alloy, some forty existing at the present time. The most widely used of these is that of the American Society for Testing Materials, B-62-28. The chemical and physical properties specified in this specification are shown below, and are probably the basis for the majority of others. Considerable research is in progress on this alloy and a revision of B-62-28 is probable.

Composition

Copper	85 ± 1%
Tin	5 ± 1
Zinc	5 ± 1
Lead	5 ± 1
Iron (max.)	0.25
Nickel (max.)	0.75
Phosphorus (max.)	0.05
Aluminum	none
Sulphur (max.)	0.05
Antimony (max.)	0.25
Total other (max.)	0.15

Physical Properties

Tensile strength (min.)	26,000 lb. per sq.in.
Yield point (min.)	12,000 lb. per sq.in.
Elongation in 2 in. (min.)	15%

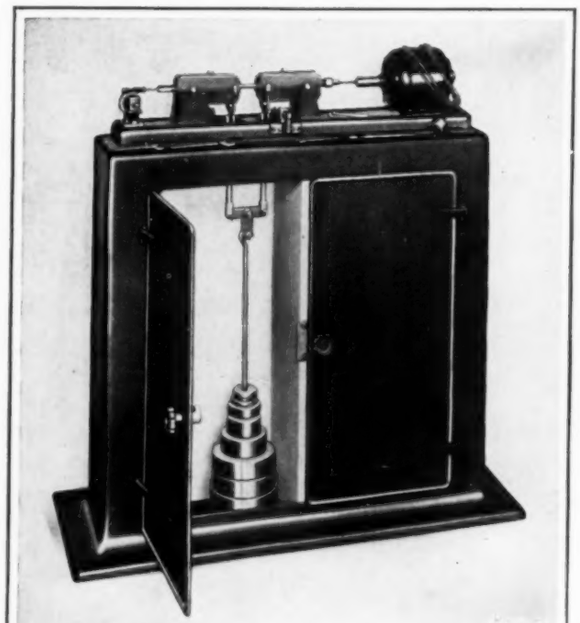
The most important factor influencing the physical properties of castings made from alloys of this type is soundness and freedom from internal porosity. The underlying causes of unsoundness and the methods for correcting are subjects which are touched upon in the data sheets of the American Foundrymen's Association dealing with this alloy. *The Foundry* has published a serial beginning Aug. 1, 1930.

Effect of Constituents

Increase of tin increases the hardness and stiffness of the alloy. Increase of zinc also acts in this direction, but to a less degree than an increase of tin. Increase of lead gradually decreases the strength, increases machinability, and lowers elongation.

Free iron even in small amounts causes hard spots. Alloyed iron, within the specification, has no pronounced effect. High iron increases hardness very materially, particularly when not in combination, or when nickel is present.

Within the maximum specified, nickel is not detrimental. Large amounts of nickel raise the freezing point and increase the sluggishness of the metal. When sufficient nickel is added the cored structure is *(Continued on page 110)*



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THE THOMPSON GRINDER COMPANY
1534 WEST MAIN STREET •• SPRINGFIELD, OHIO

BRITTLE steel after quench in 10% brine from 1450° F. . . . no draw . . . etched in acid to inspect for cracks.

	C.	Mn.	Si.	P.	S.	Alloys
Analysis:	.92	.26	.16	.020	.018	None

Rockwell hardness C. 65/68

TOUGH steel after quench in 10% brine from 1450° F. . . . no draw . . . etched in acid to inspect for cracks.

	C.	Mn.	Si.	P.	S.	Alloys
Analysis:	1.06	.30	.19	.018	.014	None

Rockwell Hardness C. 66/68

OF COURSE, we do not claim that this is a reasonable thing to do with water-hardening tool steel . . . it is a severe, abusive treatment. Perhaps the BRITTLE steel could have been made up into properly designed tools and survived a careful heat treatment.

But . . . all things being equal . . . the TOUGH tool steel will survive a difficult design or a mischance in hardening that would ruin the BRITTLE kind.

Your tool room needs that extra margin of safety to save useless waste of labor . . . and that is why Carpenter subjects its "Extra" and "Special" grades of carbon tool steel to hardness tests. Only the TOUGH kind is ever permitted to leave the mill and go into Carpenter warehouse stocks. Almost any sized round, square or flat is available for immediate delivery to your plant.

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broken up and the color of the alloy changes.

Phosphorus is usually employed as a deoxidizer. For this purpose not more than a trace need be retained in the final alloy. Appreciable amounts lengthen the freezing range of the alloy and increase its fluidity to a marked degree. Phosphorus increases the hardness and in some cases has a tendency to discolor the surface of the castings. It also increases the tendency of the castings to show "burning in" and consequent rough appearance.

Aluminum Rigidly Excluded

Aluminum is an extremely dangerous impurity and even a few hundredths of a per cent are apt to ruin the alloy, because they make the castings very unsound. Aluminum apparently alters the crystallization characteristics of the alloy very markedly. Even very small amounts sometimes cause lead sweat.

Silicon, although not mentioned in the 1928 specifications, is also a dangerous impurity. As much as 0.05% is likely to produce decided unsoundness. It apparently goes into solid solution and affects the crystallization characteristics of the alloy. In leaded alloys, the tendency toward the formation of dross from an interaction between silicon and lead compounds is pronounced.

Sulphur within the amounts allowed by the specification is not likely to cause trouble. Sulphur seems to promote sulphide inclusions, which if not too great in amount do not seriously impair the properties of the alloy.

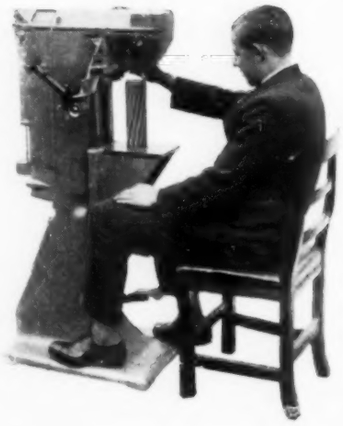
Antimony up to the maximum allowed by the specification apparently does not cause trouble. Its effect on this alloy has not been thoroughly investigated, or at least published results of investigations are scarce.

Ultimate tensile strength in average foundry practice is about 30,000 lb. per sq.in. However, foundries maintaining rigid technical control are able to exceed this average materially.

The modulus of elasticity of this alloy must be established arbitrarily, since no very definite proportional limit is apparent. At 10,000 lb. per sq.in. stress the *(Continued on page 112)*

The VICKERS HARDNESS TESTING MACHINE

. . . provides a proportional and absolute standard of hardness by the plastic indentation method. There is nothing empirical about it. It will test difficult specimens such as sheets under .007" thick; gear teeth on the working face; finished coil springs, etc., without damage. It is semi-direct reading and very fast...In research work into the constitution and properties of nitrided steel cases, after a trial of other Hardness Testing Machines, this machine was selected as the most suitable, as besides the hardness, it indicates the friability of the case, which is a measure of its wearing qualities.



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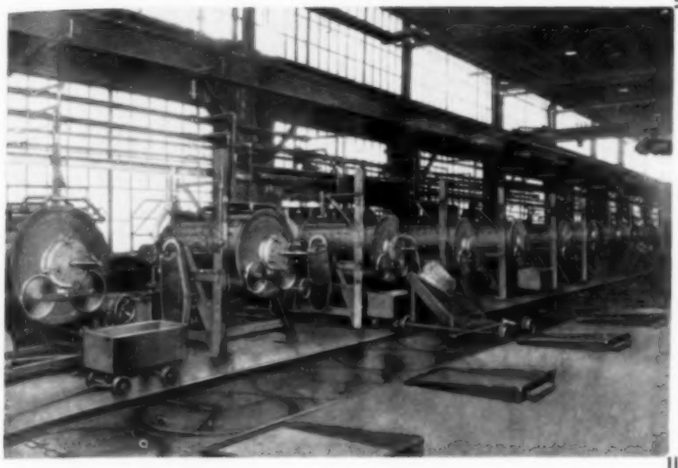

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apparent modulus is 13,000,000 lb. per sq.in.

The yield point in the specification is given as 12,000 lb. per sq.in. minimum stress required to produce 0.01 in. strain in a 2-in. gage length. In a sound, well-made alloy this point will be found to average about 15,000 lb. per sq.in. However, there is a sharp "elbow" or change in curvature in the stress-strain diagram somewhat above 10,000 lb. per sq.in.

The minimum elongation in 2-in. gage is 15%. On a good sound alloy the average will be nearer 25 and not under 20%.

Alloy is Weak Above 500° F.

At elevated temperatures the strength while under load drops gradually until 400° F. is reached, rather rapidly from 400 to 500° F. and very rapidly above 500° F. There are few tests published giving creep or flow test limiting stresses at elevated temperatures. The above suggests that this alloy, in common with others of its type, should not be used above 500° F. unless a reasonably large safety factor is employed. There is no danger of lead sweat in this alloy within the temperature range indicated if the alloy is made properly.

The Brinell hardness ranges from about 48 to 58 (500 kg.).

Rockwell hardness, using the $\frac{1}{8}$-in. ball, is about 65 to 75.

Specific gravity of sand cast alloy at 25° C. is about 8.7. This varies according to the soundness of the alloy.

Specific gravity of the chill cast alloy at 20° C. is 8.9.

Weight per cu.in.: 0.314 lb.

Pattern makers' shrinkage usually is taken as $\frac{3}{16}$ in. per ft.

The linear contraction in the range from 20 to 900° C., is 18.4×10^{-6}.

The volume shrinkage in the range from 20 to 900° C., is 5.5%.

The solidification shrinkage is 4.9%.

Izod test is about 9 ft-lb. (average of several tests).

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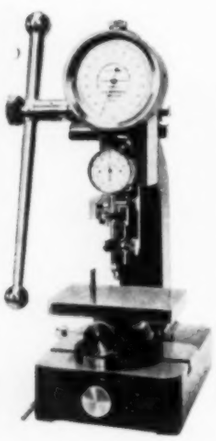

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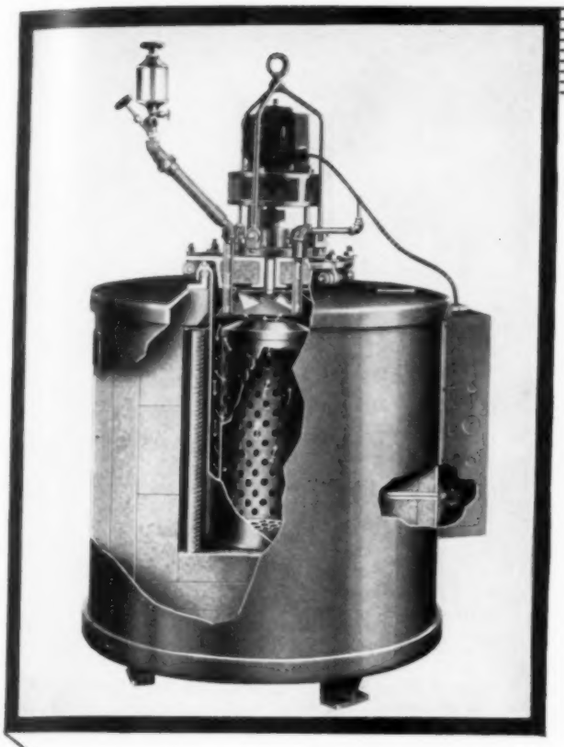

CARBONAL CONTROLS CARBURIZING

CARBONAL, dripped into the discharge of a centrifugal fan, is thrown against the hot sides of the retort where it is cracked into nascent carbon. Forced circulation distributes the carbon gases uniformly to all parts of the charge which is maintained at a constant temperature throughout.

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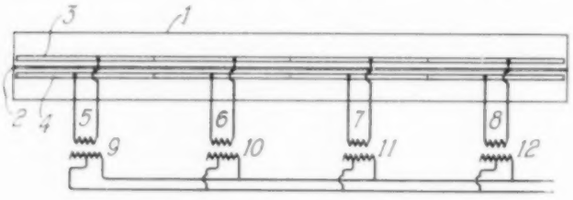
Welding Tubes Electrically, *by William E. Crawford, of Wauwatosa, Wis., assignor to A. O. Smith Corp., Milwaukee. 1,783,411; Dec. 2.* This patent has its application in the flash or resistance welding of tubular articles of a length wherein the welding current is distributed along the seam to be welded at several points. In such constructions it has been found that the current divides itself into two paths, one around the back of the tube and the other across the seam, and that despite a magnetic

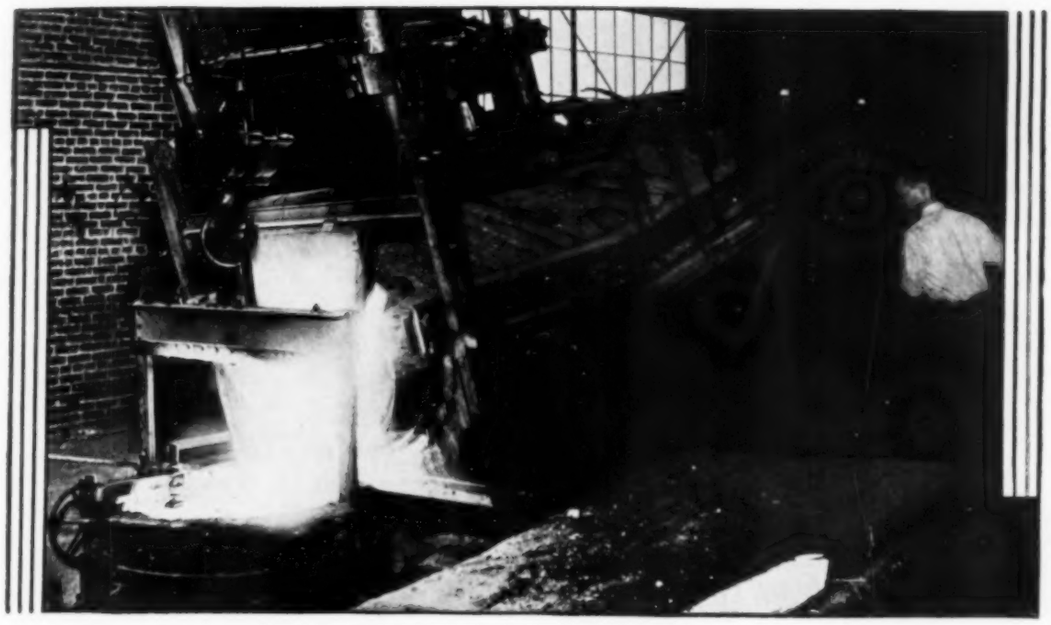


flux-carrying member inserted in the pipe to oppose such back leakage there is a materially greater back leakage of current at the ends of the pipe than in the center. Such leakage makes it difficult to heat the edges of the weld throughout the length of the article. The pipe may be formed from a flat sheet converted into a tubular blank *1*, having a longitudinal seam *2* to be welded. The welding current is applied to the seam through electrodes *3* and *4*, which may be continuous or sectional, and the welding current is preferably distributed through leads *5*, *6*, *7*, and *8*. The leads preferably comprise secondaries of a plurality of transformers *9*, *10*, *11*, and *12*, the primaries being energized from a common source of welding current. A higher initial voltage is provided at the ends of the pipe by adjusting the transformers *9* and *12* different from the transformers *10* and *11*. The voltage applied differs sufficiently to force the same amount of heating current across the edges at the ends of the pipe as is forced across the edges in the center.

Purifying Pig Iron, *by Konrad Hofmann, of Essen, Germany, assignor to Fried. Krupp Aktiengesellschaft, of Essen-on-the-Ruhr, Germany. 1,782,923; Nov. 25.*

This describes a process for eliminating from phosphorus and sulphurous pig iron the phosphorus and sulphur without oxidizing the carbon contained in the pig iron. The process includes the control of the percentage of carbon in the pig iron by suitably determining the quantity of the fining means and the carbon of the slag, and the temperature of the slag and of the pig iron bath. Preferably a desulphurizing and dephosphorizing slag is applied to the pig iron bath in a furnace of usual design, which slag contains the fining means, namely iron or manganese oxides and alkalin earth required to bind the oxide of phosphorus, P_2O_5, to which slag pulverized or granular carbon is added.

(Continued on page 128)



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Miscellaneous Chromium Alloys

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Standard Ferromanganese
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SILICON
Ferrosilicon 15%
Ferrosilicon 50%
Ferrosilicon 75%
Ferrosilicon 80 to 85%
Ferrosilicon 90 to 95%
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Calcium-Silicon
Calcium-Aluminum-Silicon
Calcium-Manganese-Silicon
Silicon-Copper
Silico-Manganese
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VANADIUM
All Grades

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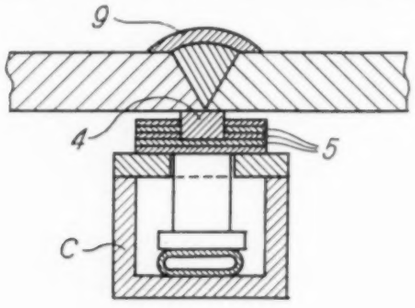
Ferro-Zirconium
Silicon-Zirconium
Zirconium-Ferrosilicon

Welding Method, *by Boris S. Robinoff, of Pittsburgh, and Sumner E. Paine and Wrignol E. Quiller, of McKeesport, Pennsylvania, assignors to National Tube Co. 1,782,316; Nov. 18.*
One of the objects of this invention is to provide a method whereby the flux is attracted to the electrode by magnetic forces, such flux having a percentage of ground or powdered ferrous oxide to make it magnetic. After the "V" shaped groove shown by the drawing is filled with flux the welding head of the welding machine is brought into proper position and an arc will be struck to melt the rod. The welding beam *C*



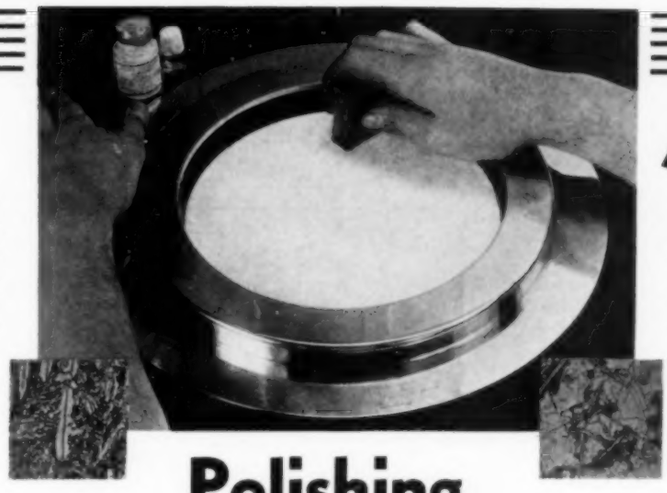
of the welding machine has a backing up bar *4* of copper and around which are mounted iron plates *5*, the bar *4* being connected to a source of current which serves to magnetize the plates *5* and form a magnetic field along the line of weld. The groove is filled with flux *9* which forms a slag *9* on top of the molten metal and through which the molten metal is deposited so as to prevent oxidation of the metal. The electrode is preferably a plain uncoated rod mounted on a reel and is continually fed down toward the work at a speed so as to deposit the required amount of welding metal. The current passing through the weld is sufficient to attract slag or flux *9* and prevent its running off.

Coating Zinc and Cadmium, *by Aladar Pacz, of East Cleveland, Ohio. 1,784,106; Dec. 9.*
This coating of metals either for preservative or decorative purposes provides a simple, inexpensive process whereby zinc and cadmium can be given a thin, adherent coating which is permanent and non-corrodible under all ordinary conditions, which is artistic and attractive, and which will serve as an enduring foundation for paint and other coatings. The invention is based upon the peculiar properties of certain molybdenum compounds. It requires depositing upon the surface of the article to be coated a coating of one or more of the lower oxides of molybdenum by dipping in an ammonium molybdate solution.

Annealing, *by John R. Cain, of Washington, D. C., assignor to the Richardson Co., of Lockland, Ohio. 1,784,221; Dec. 9.*
This invention concerns annealing in a hot bath of liquid, particularly a process for maintaining a temperature gradient in the annealing bath. Hydrocarbon oil is not readily heated by convection (internal heat transfer) currents, and this property makes such oil a particular value in the present process. The lower part of the vessel is placed within a vertical furnace of the electric resistance type, and the vessel may be preferably supported on a block of refractory material so that the lowermost part of this vessel is located in the hottest part of the furnace. A mass of lead, which will be melted by the heat, may be inserted in the furnace and above this is placed the stated hydrocarbon oil. With certain brasses or alloys it is possible to start with an initial temperature in the upper limit of the hydrocarbon oil of 200° to 250°C. progressively increasing downward until a temperature of 800° to 850°C. is reached in the lower portion of the lead bath. The temperature may be similarly reduced by removing the articles slowly.

Corrosion Fighter, *by Adolf Beck and Gustav Siebel, of Bitterfeld, Germany, assignors to I. G. Farbenindustrie Aktiengesellschaft, of Frankfort-on-the-Main, Germany. 1,783,770; Dec. 2.*
This invention relates to a process of improving the resistance to corrosion of magnesium alloys which contain a high percentage of magnesium such as 80% Mg. Such high percentage alloys frequently contain surface impurities which give rise to an accelerated corrosion. This is particularly true with pressed rolled or otherwise worked up pieces which have a skin including embedded articles of iron and decomposed organic compounds. If such articles are treated with a boiling aqueous solution of dichromates containing about 100 grams of CrO_3 per liter for an hour longer it will be found that an extremely thin transparent coating insoluble in water is formed which contains oxidic chrome compounds and has a yellowish, brass-like hue.

Fisher Alumina Polishing



Fisher Polishing Alumina produces a mirror-like polish on metallographic specimens without encasing scratches. Encased scratches develop upon etching.

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AIRPLANE MATERIALS

Materials of Construction in Aircraft Engines, R. R. Moore. *Am. Soc. Testing Matls.—Proc.*, pt. 2, 1930, pages 88-98 and (discussion) 171-214.

Paper covers briefly various steels, bronzes and brasses and light alloys that are most commonly used in construction of aircraft engines; physical properties and chemical analyses of alloys are given; applications of various alloys together with reasons for specific uses of each are explained in detail.

Ferrous Metals Used in Airplane Construction, J. B. Johnson. *Am. Soc. Testing Matls.—Proc.*, pt. 2, 1930, pages 28-33 and (discussion) 171-214.

Various types of ferrous metals which have become standardized due to cooperation between national engineering societies, government bureaus and industry in attempting to limit number of steels to minimum; chemical content and physical properties of several types have been tabulated with brief summary of principal application.

Structural and Engineering Light Alloys for Aircraft, R. L. Templin, F. V. Hartman and E. C. Hartmann. *Am. Soc. Testing Matls.—Proc.*, part 2, 1930, pages 34-40 and (discussion) 171-214.

Paper deals with wrought and cast alloys of aluminum and magnesium which are best suited to aircraft work; their advantages in general field of aircraft construction are briefly discussed; designation of various alloys available is indicated and forms in which alloys are produced commercially are given; tables of data are given on nominal composition, heat treatment, and mechanical properties.

TESTING. Mechanical Testing of Aircraft Materials, J. B. Johnson. *Am. Soc. Testing Matls.—Proc.*, part 2, 1930, pages 119-126, and (discussion) 171-214, 9 figs.

Description of tension, bend, hardness, impact, shear and torsion tests performed in connection with inspection of materials.

ALLOY STEELS

Use of Alloy Steel More Diversified, J. D. Knox. *Steel*, vol. 88, no. 1, Jan. 1, 1931, pages 253-254, 2 figs.

Statistical data on consumption of principal alloy steel products in various industries for 1926-1930.

ALUMINUM

Aluminum Sheet Production, R. J. Anderson. *Metallurgia (Manchester)*, vol. 2, nos. 11 and 12, Sept. 1930, pages 173-176, Oct., pages 211-214, vol. 3, nos. 13 and 14, Nov., pages 4-8, and Dec., pages 53-56, 7 figs.

Sept.: Compositions used for sheet rolling; kinds and grades of sheet. Oct.: Sizes, gages and tolerances; sheet tempers; heat-treated alloy sheet. Nov.: Raw materials for melting. Dec.: Furnaces for use in melting aluminum and its alloys prior to pouring rolling ingots. Bibliography.

Essais a la corrosion de l'aluminium et de ses alliages (Corrosion Test Aluminum and Its Alloys), Von Zeerleder. *Génie Civil*, vol. 98, no. 1, Jan. 3, 1931, pages 12-13, 6 figs.

Abstract of paper read at Liége Congress of Mining and Metallurgy, describing apparatus and methods, including hydrochloric acid method.

ALUMINUM ALLOYS

Oscillographic Researches on Properties of Some Light Alloys (Richerche oscillografiche sulle proprieta di alcune leghe leggere nota preliminare), E. Denina and G. Corinaldi. *Ingegnere (Milan)*, vol. 4, no. 11, Nov. 1930, pages 746-748, 1 fig., two special plates.

Report from laboratory of electrochemistry and physical chemistry of Royal School of Engineering of Turin on electrolytic and metallographic properties of alloys of aluminum.

Electrical Conductivity and Tensile Properties of Light Magnesium-Aluminium Alloys As Affected By Atmospheric Exposure, E. Wilson. *Instn. Elec. Engrs.—Jl. (Lond.)*, vol. 69, no. 408, Dec. 1930, pages 89-94, 6 figs.

One-half per cent magnesium alloy, under name of Aldrey, is being used on Continent without steel core, and paper is concerned with its exposure to atmosphere.

CORROSION. Korrosion und Korrosionsschutz von Aluminium-Walzlegierungen (Corrosion and Corrosion Prevention of Rolled Aluminum Alloys), P. Brenner. *Zeit. fuer Metallkunde*, vol. 22, no. 12, Dec. 1930, pages 420-422, 2 figs.

Discussion of paper indexed in Engineering Index 1930, from Oct. issue of same journal.

NOTCH TOUGHNESS. Ueber die Kerbfaehigkeit einiger Aluminiumlegierungen insbesondere bei tiefen Temperaturen (Notch Toughness of Some Aluminum Alloys, Especially at Low Temperatures), W. A. Gueldner. *Zeit. fuer Metallkunde*, vol. 22, no. 12, Dec. 1930, pages 412-416, 10 figs.

Measurement of torsion; determination of flow spaces; investigation of change of specimens at temperatures up to minus 190 deg. cent.; it is shown that behavior of materials at lower temperature is determined most accurately by notched-bar test. (Concluded.)

BEARINGS

Facts about Bearings and Bearing Metals, J. D. Lloyd. *Machy. (N. Y.)*, vol. 37, no. 4, Dec. 1930, pages 284-285.

Composition of bearing metals, bearing clearances, and other factors to be considered in attaining maximum bearing efficiency; tables give data on approximate analysis of various bearing metals and clearances for horizontal cylindrical bearings.

Antifriction White Metals, W. Lambert. *Metal Industry (Lond.)*, vol. 37, no. 24, Dec. 12, 1930, pages 553-554 and 558.

Desirable properties of bearing metal; heterogeneity; characteristics of good bearing metal; care needed in ordering; babbitt metal; qualities of ideal lining metal; lead-base vs. tin-base white metal. Abstract of paper read before Inst. Engrs. and Shipbldrs., Dec. 2.

(Continued on page 132)

CYANIDE REHEAT

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Cyanide Reheat Is...

a simple heating of the part in a cyanide bath. The time of treatment varies from 10 to 40 minutes. In the cyanide dip and wash the part is heated to temperature in an air furnace and then treated respectively in the cyanide bath for 15 seconds and 2 minutes. These treatments produce *high nitrogen surfaces* which cannot be obtained with any other molten bath.

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gears, nuts, bolts, splined shafts, couplings, cam shafts and many other products where maximum wear resistance is desired. It prevents tooth-pitting of gears in service.

Cyanide Reheat Imparts...

a marked increase in wear resistance and surface hardness to plain carbon, oil hardening alloy and carburized steels. No finishing operations are necessary after the Cyanide Reheat. There is no scale.

Cyanide Reheat...

method permits ready control of the surface properties and depth of the *high nitrogen surface layer*. The bath is noncorrosive.

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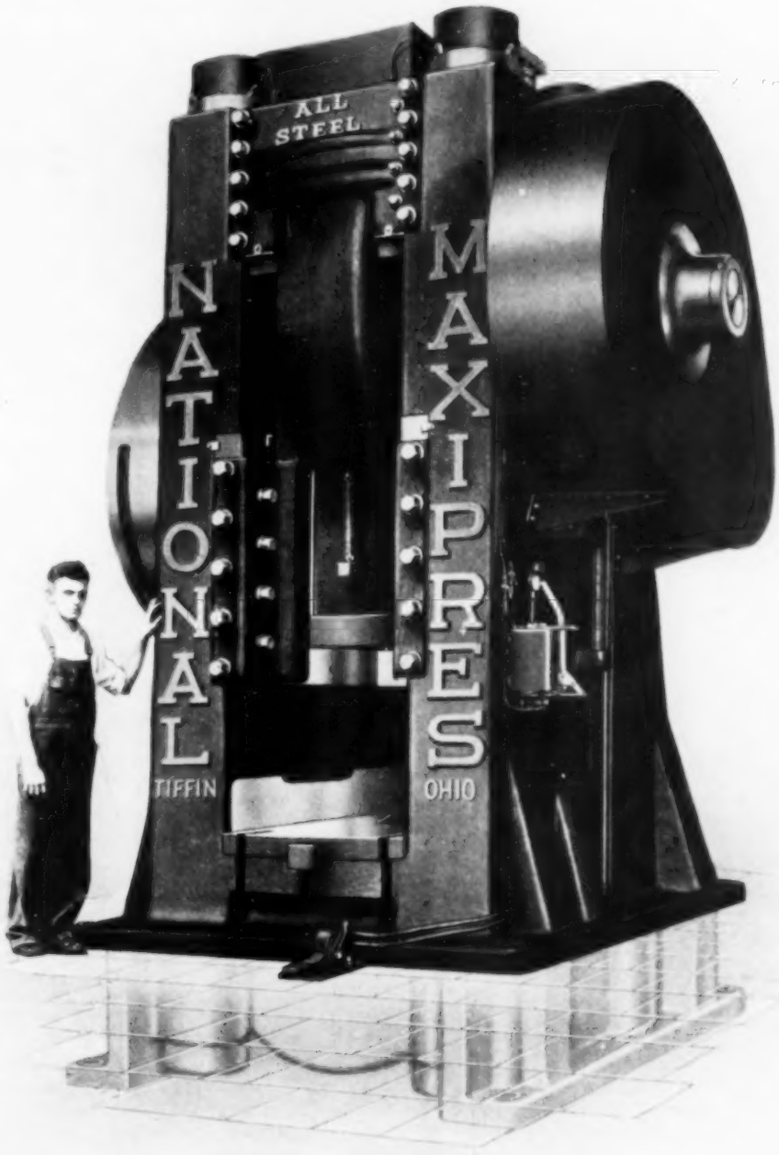

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CAST IRON

TESTING. Simple Methods for Improvement and Control of Gray Iron Manufacture, L. F. C. Girardet. *Am. Foundrymen's Assn.—Trans. and Bul.*, vol. 1, no. 11, Nov. 1930, pages 624-643, 12 figs.

Routine methods for controlling quality at St. Die (Vosges) foundry, France; control of mechanical properties, metallographic structure and chemical analysis; Fremont shear test; metallographic examination of specimens to show structure and graphite characteristics are detailed.

CORROSION

Interesting Case of Destruction of Plating of Distilling Tank Due to Cementation of Materials (O ciekawym wypadku zniszczenia blachy kotla destylacyjnego przez nacementowanie), M. Strzalko. *Technika Cieplna (Warsaw)*, vol. 8, no. 7, July 25, 1930, pages 133-137, 8 figs.

Metallographic study of unique case of steel corrosion.

Corrosion-Prevention Methods as Applied in Aircraft Construction, H. S. Rawdon. *Am. Soc. Testing Matls.—Proc.*, pt. 2, 1930, pages 61-67 and (discussion) 171-214.

Based on information supplied by leading aircraft manufacturers, résumé of present commercial practice on corrosion-prevention methods in use has been prepared; survey shows that Army and Navy requirements are doing great deal to bring about uniformity in commercial practice.

Some American Researches on the Fatigue of Metals, D. J. McAdam, Jr. *Metallurgist (Supp. to Engineer, Lond.)*, Dec. 1930, pages 183-186, 4 figs.

Review of paper on influence of Stress Range and Cycle-Frequency on Corrosion; previously indexed from Am. Soc. Testing Matls.—Proc., of mtg. June 23.

TESTING. Resistance of Metal to Decomposition of Caustic Acids and Alkalis (Widerstandsfachigkeit der Metalle gegen Zersetzung durch aetzende Saeuren und Alkalien), W. Kollrepp. *Zeit. fuer die gesamte Giessereipraxis (Berlin)*, vol. 51, nos. 50 and 51-52, Dec. 14, 1930, *(Metall)* pages 201-202, and Dec. 23, pages 205-206.

Resistance of different metals to chemical corrosion; use of suitable deoxidizing agents.

Rules for Practical Testing of Corrosion Resistance of Steel (Richtlinien fuer die praktische Pruefung von Staehlen auf ihren Korrosionswiderstand), E. H. Schulz. *Stahl und Eisen (Duesseldorf)*, vol. 50, no. 36, Sept. 4, 1930.

CUTTING MATERIALS

The New Alloys and Machine Tool Design, F. W. Shaw. *Metallurgia (Manchester)*, vol. 3, no. 14, Dec. 1930, pages 57-58, and 61.

Development of alloys for cutting tools is surveyed, and function of elements in these alloys is discussed in light of present progress; Taylor-White steel; stellite; Widia; how elements function in alloys. (To be continued.)

Tool-Steel Tools, A. H. D'Arcambal. *Am. Soc. Mech. Engrs.—Advance Paper* no. 16, for mtg. Dec. 1-5, 1930, 8 pages, 13 figs.

Factors that govern life of metal-cutting tools made from carbon alloy, and high speed tool steels; design, steel, and treatment; cutting fluids or coolants as affecting life of tool; necessity of employing proper grinding wheels and correctly using them.

Cutting Tools Manufactured In Specially Designed Plant, B. Finney. *Iron Age*, vol. 126, no. 26, Dec. 25, 1930, pages 1908-1911 and 1978, 5 figs.

Methods used by Michigan Tool Co., Detroit; reduction in operating costs by constructing one-story plant specially designed for manufacture of cutting tools and equipped with high-production machine tools and other machinery built for its operations.

TESTING. A Test of Machining Quality, Wallichs and Krekeler. *Metallurgist (Supp. to Engineer, Lond.)*, Oct. 1930, pages 149-150.

Test by means of appliance known as Leyensetter double-pendulum simple mechanical device; results obtained in testing effect of increasing cutting speed on two steels of widely different physical properties are shown in graphs; pendulum appears to furnish delicate test of "sharpness" quality which hitherto has not been at all easy to measure. Translated abstract of paper previously indexed from Archiv fuer das Eisenhuettenwesen, July 1930.

TUNGSTEN CARBIDE. Tungsten-Carbide Cutting Materials. *Metallurgia (Manchester)*, vol. 2, no. 11, Sept. 1930, page 168.

Abstract of Progress Report no. 2 of Subcommittee on Tungsten-Carbide Cutting Materials of the A.S.M.E. Special Research Committee on the Cutting of Metals, previously indexed from Mech. Eng., Aug. 1930.

DIE CASTING

Die-Casting Plant Laid Out on Engineering Basis, S. G. Koon. *Iron Age*, vol. 126, no. 22, Nov. 27, 1930, pages 1593-1597, 4 figs.

Layout, equipment and production methods at plant of Allied Die Casting Corp., Long Island City; flooring and machine foundations; factors of safety.

Development of Zinc-Base Die-Casting Alloys, D. L. Colwell. *Am. Soc. Testing Matls.—Proc.*, vol. 30, pt. 2, of mtg. June 23-27, 1930, pages 473-489 and (discussion) 490-492, 13 figs.

History of improvement of zinc-base die-casting alloys is illustrated in series of charts, which show effects of normal and accelerated aging on size and physical properties of zinc base die castings; data from tests; conclusions reached.

ELECTRIC FURNACES

The Use of Electricity in the Heat Treatment and Welding of Metals, A. N. Otis and W. L. Warner. *Mill and Factory Illustrated*, vol. 5, no. 1, Jan. 1930, pages 48-50 and 92, 9 figs.

Features of electrically-heated water-sealed furnaces of Kenworthy type widely used for bright annealing copper wire and similar products.

Theoretical Viewpoints in Construction of High-Frequency Furnaces (Naagra Teoretiska Synpunkter vid Konstruktion av Hoegfrekvensugnar), L. Dryfus. *Teknisk Tidskrift (Stockholm)*, vol. 60, no. 49, Dec. 6, 1930 (Elektroteknik), pages 225-230, 3 figs.

Electric problems of melting furnaces; factors influencing determination of electric field distribution, power factor, heat generation in furnace, charge and furnace coil and considerations influencing selection of frequency.

Bright-Annealing by the Gruenewald Process, F. W. Mueller. *Metallurgia (Manchester)*, vol. 3, no. 14, Dec. 1930, pages 69-70, 3 figs.

To maintain clean bright surface on annealed metal, precautions against oxidation are necessary, as well as regularity of suitable temperature; features of Gruenewald furnace; method of working; furnace layout; temperature and power regulation graph. Translated from "Das Gruenewald-Blankgluehverfahren," Metallwirtschaft, 20 June 1930.

Favors Electric Furnaces for Special Steels. *Elec. World*, vol. 96, no. 26, Dec. 27, 1930, pages 1184-1186, 8 figs.

It is essential that foundrymen turn out dependable alloys day in and day out under all sorts of conditions; requiring careful study of mixture, strict grading of raw materials and accurate control of foundry practice; electric furnace is essential part of picture because it combines two qualities of close control and flexibility of operation.

ELECTRIC WELDING

Electric Welding; Annual Report of Committee on Electric Welding. *Am. Inst. Elec. Engrs.—Trans.*, vol. 49, no. 4, Oct. 1930, pages 1699-1701.

Fundamental Problems of Electric Resistance Welding (Einige grundsaetzliche Fragen der elektrischen Widerstandschweissung), F. Goldmann. *Elektroschweissung (Braunschweig)*, no. 12, Dec. 1930, pages 225-230, 6 figs.

Proposal for new conceptions; determining factors; inadmissibility of reforging of thickening in butt welding; causes of red hot and cold breakability; necessity of removal of heavy oxide and scale layers at weld; vapor formation as cause of penetration of different materials in welding.

Electric Welding of Steel, T. McLean. *West. Soc. Engrs.—Jl.*, vol. 35, no. 6, Dec. 1930, pages 415-422, 7 figs.

General information about applications of welding in manufacture of large products, such as welded pressure vessels; author considers code specifying exact procedure for welding is obsolete and that manufacturers should be willing to submit welded products to acceptance tests.

(Continued on page 140)

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FATIGUE

Report of Research Committee on Fatigue of Metals. *Am. Soc. Testing Matls.—Proc.*, vol. 30, part 1, of mtg. June 23-27, 1930, pages 259-310, 24 figs.

Fracture Under Repeated Stress, H. F. Moore; Mechanical Hysteresis and Fatigue, J. B. Kommers; Detection of Incipient Fatigue Failures, R. L. Templin; Effect of Alloying and Heat Treatment on Endurance Limit of Steel, H. W. Gillett; Overstressing in Fatigue, T. McL. Jasper; Cold Working, T. McL. Jasper; Strengthening by Understressing, H. W. Gillett; Stress Concentration and Fatigue Strength, R. E. Peterson; Corrosion-Fatigue; Significance of Fatigue Test Results, H. F. Moore. Bibliography.

Report of Research Committee on Fatigue of Metals. *Am. Soc. Testing Matls.—Proc.*, vol. 30, pt. 1, of mtg. June 23-27, 1930, pages 259-310, 24 figs.

Activities of committee; appendices include: Experimental Knowledge and Theories of Fatigue Phenomena in Metals; Endurance Limit, Machines, Specimens, and Accelerated Test, R. R. Moore; Correlation of Endurance Limit With Other Physical Properties, J. R. Townsend; Effect of Range and Kind of Stress on Fatigue Strength, J. B. Kommers; Fatigue of Metals as Affected by Metallographic Features, H. R. Rawdon.

FORGING

Precision Forging—the Newer Idea on Drop Forgings, A. H. Deute. *Iron Age*, vol. 126, no. 25, Dec. 18, 1930, pages 1840-1841 and 1902, 4 figs.

Methods used by Billings & Spencer Co., Hartford, Conn., in producing accurate forgings and reducing machining cost.

Mechanization of Forging Procedure (La mécanisation du travail de forge), P. Lenormand. *Arts et Métiers (Paris)*, vol. 83, no. 121, Oct. 1930, pages 408-419, 8 figs.

Principles of forge-shop organization with particular regard to mass production; requirements of forging-machine design and simplicity of operation; floor plan illustrates layout of machine shop.

FURNACES

Ford Forges with Electric Heat. *Elec. World*, vol. 96, no. 20, Nov. 15, 1930, pages 902-905, 6 figs.

At present 55 electric furnaces are used for heating only comparatively small forgings as universal joint housings, front-wheel spindles, steering-gear spiders, ring gears, rear axle shafts with forged gears on their ends, etc.; temperatures necessary for forging steel vary from 1900 to 2450 deg. fahr.; most of work in Ford plant is heated to 2300 to 2350 deg.

Factors Influencing the Design of Normalising Furnaces, E. E. Griffiths. *Metallurgia (Manchester)*, vol. 3, no. 14, Dec. 1930, pages 62-64 and 68, 6 figs.

Principal types of normalizing furnaces; general requirements of all normalizers; process requirements; prevention of damage to surface of sheets; labor cost and general conditions.

Factors Influencing the Design of Normalising Furnaces, E. E. Griffiths. *Iron and Coal Trades Rev. (Lond.)*, vol. 121, no. 3275, Dec. 5, 1930, pages 835-837, 7 figs.

General review; normalized and annealed sheets compared; principal types of normalizing furnaces; general requirements; specific requirements for various types of sheet and tinplates; process requirements; features of furnace operation. Read before Instn. Mech. Engrs. at Swansea.

GAS FURNACES

The Gas Industry's Research Program in Metallurgy, E. D. Milener. *Am. Gas Assn. Monthly*, vol. 13, no. 1, Jan. 1931, pages 15-19.

Experimentation with gas forging furnaces being conducted by University of Michigan covering burning, overheating, scaling, decarburization rates of heat penetration, and other factors that enter into heating and production of quality forgings. Paper read before Am. Soc. Steel Testing, Dec. 17, 1930.

GEARS

Some Common Defects in Steel for Gear Manufacture, F. W. Rowe. *Metallurgia (Manchester)*, vol. 2, no. 12, Oct. 1930, pages 198-200, 10 figs.

Residual pipe and "V" segregates; ingot corner weakness; slag inclusions; variation in analyses.

The Selection and Treatment of Gear Materials, F. W. Rowe. *Foundry Trade Jl. (Lond.)*, vol. 43, no. 748, Dec. 18, 1930, pages 427-430 and 432, 7 figs.

Review of important factors such as, resistance to wear, resistance to stresses other than wear, pitting in gears, shock strength; data on physical properties and composition of cast iron, cast steel, mild steel, carbon steel, nickel and chromium steel, etc.; application of bronze for gears; heat-treatment of steel gears; case-hardening. Extract of paper read before mtg. of Manchester Assn. of Engrs.

HEAT TREATMENT

Selection of Form in Consideration of Economic Hardening Methods (Konstructive Gestaltung unter Beruecksichtigung wirtschaftlicher Haerteverfahren), G. Oehler and A. Kropf. *Maschinenbau (Berlin)*, vol. 9, no. 24, Dec. 18, 1930, pages 793-897, 25 figs.

Stresses caused by improper design of machine parts are illustrated by sketches; various machine elements serve as example for demonstrating proper design and treatment in hardening; data on quenching methods and means.

Les traitements préliminaires des aciers (Initial Treatment of Steels), Pomey. *Revue de l'Industrie Minérale*, no. 240, Dec. 15, 1930, pages 527-544, 18 figs.

Different kinds of preliminary treatments; heredity of steel; crystallization; case of alloy with more than two constituents; more complex cases where eutectoid intervenes; influence of speed of cooling; heterogeneity; structure of pearlitic steels; comparison between forged and rolled metal; phenomenon of coalescence; eutectoid formation.

Relation of Hardness of Carbon Steels to Particle Size of Iron Carbide (Die Abhaengigkeit der Haerte bei Kohlenstoffstaehlen von der Teilchengroesse des Eisencarbids), S. Shimura and H. Esser. *Stahl und Eisen (Duesseldorf)*, vol. 50, no. 48, Nov. 27, 1930, pages 1674-1675, 3 figs.

In order to determine this relationship, heat treatment was necessary, which permitted wide variation in size of iron-carbide inclusions in steel; results of hardness tests show that with increasing particle size, hardness decreases, in case of all steels.

HIGH SPEED STEEL

Effect of Carbon Gases on Steel, M. Winter and P. B. Crocker. *Heat Treating and Forging*, vol. 16, no. 11, Nov. 1930, pages 1450-1451, 1 fig.

Results of investigation in which gases of varying carbon monoxide content were brought in contact with high-speed steel.

The Mechanism of Quenching High Carbon Steel Tools, P. J. Haler. *Fuels and Furnaces*, vol. 8, no. 12, Dec. 1930, pages 1653-1659, 12 figs.

Quenching of various types of high carbon or case hardened steel; mechanism of cooling and effect of heat upon stream lines of piece being quenched, quenching of milling cutters, plunging speed and quenching of flat circular disc.

Effect of Heat Treatments on Efficiency of High-Speed Steels, E. Kothny. *Iron Age*, vol. 126, no. 25, Dec. 18, 1930, pages 1848-1852, 11 figs.

Results of tests show that cutting efficiency of high-speed steels, working on hard and medium-hard steels, can be considerably increased by tempering at 590 deg. cent.; tables give data on appearance of fracture and behavior of turning tools when touched by file; time of turning in hardened and in hardened-tempered condition, depth of cut, 4 mm. feed, 1.5; microphotograph illustrates crystal structure obtained by various kinds of heat treatment procedures.

HOT ROLLING

Tests on Resistance to Deformation and Trend of Deformation during Hot Rolling of Low-Carbon Ingot Steel in Temperature Range of 700 to 1200 Deg. (Versuche ueber den Formaenderungswiderstand und den Formaenderungsverlauf beim Warmwalzen von kohlenstoffarmen Flusstahl im Temperaturbereich von 700 bis 1200 Deg.), *Institut fuer Eisenforschung (Duesseldorf)*, vol. 12, no. 15, 1930, pages 225-244, 25 figs.

(Continued on page 142)

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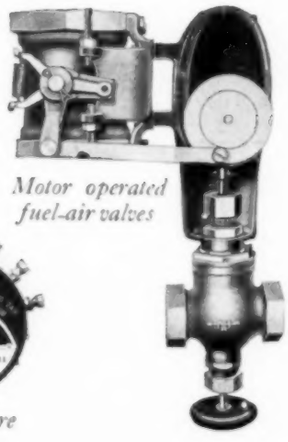

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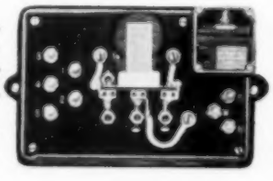

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By measurement of rolling pressure in rolling tests on flat bars, information was obtained concerning deformation resistance of mild ingot steel at temperatures of 700 to 1200 deg.

Influence of Degree of Rolling, Rolling Temperature and Cooling Conditions on Mechanical Properties and Structure of Low-Carbon Ingot Steel (Ueber den Einfluss des Walzgrades, etc., auf die mechanischen Eigenschaften und das Gefuege von kohlenstoffarmen Flusstahl), A. Pomp and E. Fangmeier. *Mitteilungen aus dem Kaiser-Wilhelm-Institut fuer Eisenforschung (Duesseldorf)*, vol. 12, no. 15, 1930, pages 245-261, 11 figs.; see also *Stahl und Eisen (Duesseldorf)*, vol. 60, no. 49, Dec. 4, 1930, pages 1721-1723, 1 fig.

Review of literature on influence of hot rolling; on properties and structure of steel; results of tests; mechanical properties and grain size as affected by air and kieselgur cooling.

IRON AND STEEL

The Change of Density in Iron and Steel Caused by Cold Working and by Tempering, K. Tamaru. *Tohuku Imperial Univ.—Sci. Reports (Sendai)*, vol. 19, no. 4, Oct. 1930, pages 437-448, 4 figs.

Density determined at different stages of tempering and causes of change of density explained.

Oxygen in Iron (Sauerstoff im Eisen), I. Feszczenko-Czopiwski and St. Orzechowski. *Zeit. des Oberschlesischen Berg- und Huettenmaennischen Vereins (Katowice)*, vol. 69, no. 12, Dec. 1930, pages 652-658, 7 figs.

Review of researches on influence of oxygen on properties of steel; solubility of oxygen in iron; oxygen content causes coarse grain; so-called abnormal steel shows tendency to embrittlement at high temperatures; aluminum as deoxidizing agent; negative influence of oxygen on impact strength.

MAGNESIUM ALLOYS

Proprieta dinamiche delle leghe ultraleggere (Dynamic Properties of Extra-Light Alloys), I. Musatti. *Metallurgia Italiana*, vol. 22, no. 14, Dec. 1930, pages 1052-1068.

Report on experimental study, made at Ernesto Breda Research Institute, of alloys of magnesium, zinc, aluminum and copper, with special reference to strength under repeated bending and notched-bar impact.

Magnesium Alloy Castings, E. Player. *Metallurgia (Manchester)*, vol. 3, no. 14, Dec. 1930.

Characteristics of magnesium alloys and some of the principles involved in production of sound castings; strength figures and mass-strength ratio of elektron magnesium alloys, compared with other metals in common use; alloy composition; melting; molding; machining. Read before Inst. of Metals and Inst. of British Foundrymen.

METALLOGRAPHY

Martensite System (Ueber den Martensit), S. Steinberg and H. Hanemann. *Stahl und Eisen (Duesseldorf)*, vol. 50, no. 51, Dec. 18, 1930, pages 1780-1782.

Polemic relating to paper by K. Gebbard, H. Hanemann and A. Schrader, indexed in Engineering Index 1929, page 1035, from Archiv fuer das Eisenhuettenwesen, May 1929; Steinberg disagrees with above author's theory that martensite is heterogeneous mixture of phases with different carbon contents; he believes that another explanation must be offered for heterogeneity.

Structure of Pig and Cast Iron (Gefuege-Ausbildung von Roh- und Gusseisen), H. Pinsl. *Giesserei Zeitung (Berlin)*, vol. 27, no. 16, Aug. 15, 1930, pages 436-447.

Numerous photomicrographs are presented which were developed by author and exhibited at last foundry exhibition in Duesseldorf; photographs visualize structure of cast and pig iron, and were selected from more than 1000 photomicrographs.

METALS

EMBRITTLEMENT. Brittle Fracture of Metals, B. H. Haigh. *Engineering (Lond.)*, vol. 130, no. 3387, Dec. 12, 1930, pages 752-753.

Brittle fractures due to fatigue; resistance to fatigue. Abstract of last of three lectures delivered at King's College, Nov. 17.

(Continued on page 144)

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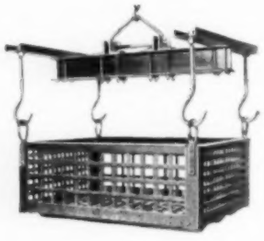

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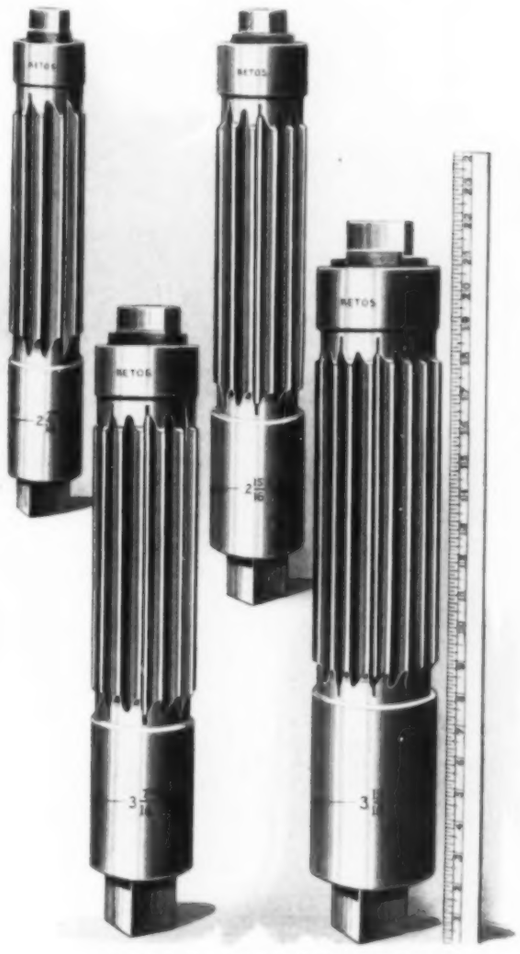

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HARDENING. Surface Hardening, A. E. Shorter. *Iron and Coal Trades Rev. (Lond.)*, vol. 121, no. 3272, Nov. 14, 1930, page 725.

Brief abstract of paper read before Instn. Welding Engrs., previously indexed from Welding Jl.

MACHINABILITY. The Problem of Machinability Measurement, E. G. Herbert. *Metallurgia (Manchester)*, vol. 2, nos. 11 and 12, vol. 3, no. 13, Sept. 1930, pages 169-171 and (editorial) page 167, Oct., pages 206-208, and Nov., pages 13-15, 10 figs.

Sept.: Scale of machinability analogous to scales of hardness and tensile strength would assist choice of materials for specific purposes; determination by measurement. Oct.: Anomalies of direct measurement; study of cutting action; work-hardening capacity; hardness induced by cutting tools; Nov.: Law of machinability; hardness of the chip as a measure.

PLASTICITY. Deformation and Strength of Materials (Werkstoffverformung und Festigkeit), E. Schmid. *Physikalische Zeit. (Leipzig)*, vol. 31, no. 20, Oct. 15, 1930, pages 892-896, 10 figs.

Report on experimental work for attempted explanation of plasticity of metals through properties of crystals; properties of single metallic crystals; comparative discussion of mechanical behavior of single crystals and of multicrystalline structures.

NITRIDING

Nitriding; Its Present and Future Status, V. O. Homerberg. *Iron Age*, vol. 127, no. 1, Jan. 1, 1931, page 52.

Development of nitriding processes including investigations conducted at laboratory of Nitralloy Corp.; gray cast iron that can be nitrided to give satisfactory case; nitriding in presence of carburizing agent; protective agents against nitriding; effect of pressure; role played by hydrogen; x-ray studies.

American Developments in Nitrogen Hardening. *Metallurgist (Supp. to Engineer, Lond.)*, Dec. 1930, pages 181-182.

Review of symposium in program of "Metals Week," held in Chicago, September; subjects discussed indicate extensive developments of process, since they relate to such matters as difficulties encountered in long-continued production work by fact that containers or "boxes" themselves become nitrided and disintegrate, or to difficulties encountered in nitrogen hardening of large forgings.

Nitrogen in Mild Steel, W. Koester. *Metallurgist (Supp. to Engineer, Lond.)*, Dec. 1930, pages 186-188.

Abstract translated from paper in Archiv fuer das Eisenhuettenwesen, Apr. 1930, in which it is suggested that as changes occur in alpha iron phase, they cannot be of allotropic nature, but must be constitutional and that, therefore, solubility of certain substances in alpha iron must be dependent on temperature.

Nitrided Steel and Its Properties, J. H. Higgins. *Heat Treating and Forging*, vol. 16, no. 12, Dec. 1930, pages 1527-1529.

Review of important points concerning production, heat treatment and use; steel selection; forging; machining; quenching and tempering; decarburization; corrosion; welding; effect of heat on case; renitriding. Paper delivered before Am. Soc. Steel Testing.

NON-FERROUS ALLOYS

Some Non-Ferrous Engineering Alloys, W. Lambert. *Metallurgia (Manchester)*, vol. 3, no. 14, Dec. 1930, pages 65-68.

Resistance to corrosion, thermal conductivity, anti-frictional qualities, dependability, machinability, specific gravity, and artistic attractiveness; manganese bronze; aluminum bronze; gunmetal; phosphor bronze; lead bronzes; monel metal; anti-friction white metals; qualities of ideal lining metal. Read before Instn. of Engrs. and Shipbldrs. in Scotland.

A List of Alloys, W. Campbell. *Am Soc. Testing Matls.—Proc.*, vol. 30, pt. 1, of mtg. June 23-27, 1930, pages 336-397.

In connection with activities in nomenclature of non-ferrous metals and alloys of Committee B-2 on Non-Ferrous Metals and Alloys, in order to show difficulties met with when attempt is made to formulate logical and scientific classification of alloys, list of alloys has been compiled.

Some Non-Ferrous Engineering Alloys, W. Lambert. *Machy. Market (Lond.)*, nos. 1571 and 1572, Dec. 12, 1930, pages 21-22 and Dec. 19, pages 17-18 and 22.

Dec. 12: Use of non-ferrous alloys is favored from considerations of resistance to corrosion, thermal conductivity, anti-frictional qualities, dependability, machinability, specific gravity, and artistic attractiveness; brasses; manganese bronze; aluminum bronze; gunmetal and phosphor bronze. Dec. 19: Lead bronzes, monel metal anti-friction white metal; desirable properties of bearing metal; qualities of ideal lining metal. Paper read before Instn. Engrs. and Shipbldrs.

LIGHT. Light Metals and Their Alloys (Die Leichtmetalle und ihre Legierungen), F. V. Lindner. *Flugwesen (Prague)*, vol. 10, no. 10-11, 1930, pages 115-118.

Review of physical properties and uses of aluminum and magnesium with particular regard to alloying properties of beryllium and lithium.

TEMPERATURE EFFECT. Properties of Non-Ferrous Alloys at Elevated Temperatures, C. L. Clark and A. E. White. *Metal Industry (Lond.)*, vol. 37, no. 26, Dec. 26, 1930, pages 601-604, 5 figs.

Chemical composition and mechanical condition of non-ferrous alloys investigated; tensile strength of non-ferrous alloys at various temperatures; proportional limit; per cent elongation, and per cent reduction of area of non-ferrous alloys at elevated temperatures; creep characteristics of monel metal at various temperatures. (To be concluded.) Paper presented before Am. Soc. Mech. Engrs., Dec. 1-5, 1930.

PICKLING

The Pickling and Cleaning of Metals, D. Brownlie. *Sheet Metal Industries (London)*, volume 4, number 8, December 1930, pages 655-656.

Some considerations of chemical reactions involved. (Continuation of serial.)

REFRACTORY MATERIALS

Progress in Fields of Refractory Materials (Fortschritte auf dem Gebiete der feuerfesten Baustoffe), E. H. Schulz, F. Hartmann and A. Kanz. *Stahl und Eisen (Duesseldorf)*, vol. 50, no. 48, Nov. 27, 1930, pages 1677-1681.

Standardization of Refractory Materials (Die Normung feuerfester Baustoffe). *Tonindustrie Zeitung (Berlin)*, vol. 54, nos. 51 and 52, June 26, 1930, pages 846-848 and June 30, pages 861-863, 6 figs.

Tentative D.I.N. specification for testing refractory materials; resistance to influence of solid and liquid materials at high temperature; slagging resistance; determination of resistance against sudden changes in temperature.

HEAT CONDUCTIVITY. Heat-Conductivity Measurements of Refractory Material (Waermeleitfaehigkeitsmessungen an Feuerfesten Materialien), H. Golla and H. Laube. *Tonindustrie-Zeitung (Berlin)*, vol. 54, nos. 90, 91 and 93, Nov. 10, 1930, pages 1411-1414, Nov. 13, pages 1431-1432, and Nov. 20, pages 1458-1460, 9 figs.

Methods and equipment employed for heat-conductivity measurement; results are shown in curves; comparison of silica brick and firebrick.

MANUFACTURE. Efficiency Handling of Grog for Refractories, C. R. F. Threlfall. *Brick and Clay Rec.*, vol. 77, no. 12, Dec. 2, 1930, pages 649-650, 652-653, 670 and 672.

Use of grog in manufacture of refractories to reduce lamination in plastic clays, in increasing porous state in clay mass, and in enabling ware to withstand sudden changes in temperature. Abstract of paper read before Brit. Ceramic Soc.

SHEET STEEL

Manufacture of Steel Sheets, E. S. Lawrence. Cleveland, O., Penton Publishing Co., 1930, 233 pages, illus., diagrs., $6.15.

Describes sequence of operation in sheetmaking from manufacture of steel to finished sheet, with especial reference to production of high grade sheets for automobile bodies; influence of various methods upon quality of product and causes and prevention of defects are given attention; description follows current practice and is devoid of unnecessary technicalities. Eng. Soc. Lib., N. Y.

(Continued on page 147)

The Modernization of Existing Hot Sheet Mills, R. J. Wean. *Rolling Mill Jl.*, vol. 4, no. 12, Dec. 1930, pages 659-661, 2 figs.

Recent developments that have been made to lower cost and permit conventional type sheet mills to utilize present investment, maintain employment and permit producer to operate at profit.

Influence of Shape of Specimen on Notch Toughness of Thick Sheet Iron of Different Composition and Heat Treatment (Einfluss der Probenform auf die Kerbzaehigkeit von Grobblechen verschiedener Zusammensetzung und Waermebehandlung), F. Koerber and K. Wallmann. *Mitteilungen aus dem Kaiser-Wilhelm-Institut fuer Eisenforschung (Duesseldorf)*, vol. 12, no. 13, 1930, pages 193-202, 7 figs; see also *Stahl und Eisen (Duesseldorf)*, vol. 50, no. 49, Dec. 4, 1930.

Notch hardness of different rolled and annealed and heat-treated plates, measured on three forms of test pieces; comparison of results.

Influence of Degree of Rolling, Rolling End Temperature and Heat Treatment on Mechanical Properties, Sensitivity to Aging and Structure of Thick Sheet Iron (Einfluss des Walzgrades, der Walzendtemperatur und der Waermebehandlung auf die mechanischen Eigenschaften, etc.), F. Koerber and K. Wallman. *Mitteilungen aus dem Kaiser-Wilhelm-Institut fuer Eisenforschung (Duesseldorf)*, vol. 12, no. 13, 1930, pages 171-191, 94 figs. partly on supp. plates.

Four steels of different carbon and silicon content were rolled at 900, 800 and 700 deg. cent. to plates of 25, 20 and 15 mm. thickness and investigated to determine tensile strength, yield limit, elasticity, shrinkage, elongation and notch toughness.

STAINLESS STEEL

Rustless Steel's Outlook One of Continuing Promise. *Iron Age*, vol. 127, no. 1, Jan. 1, 1931, pages 84-86, 2 figs.

Principal application of stainless steel in various industries, particularly automotive, building and chemical industries.

The Fabrication of Plant in Acid-Resisting Steels, C. C. Hall. *Welding Jl. (Lond.)*, vol. 27, no. 327, Dec. 1930, pages 358-364.

Most important aspects of plant fabrication, more particularly welding aspect; explanation regarding special steels; processes involved in production of plant in austenitic steels; cold forming of special steels; welding of steels. Paper presented before Instn. Welding Engrs.

ELECTRODE PROPERTIES. Electrode Properties of Stainless Steel, E. Newberry. *Am. Electrochemical Soc.—Preprint*, no. 58-25, for mtg. Sept. 25-27, 1930, pages 335-338 and (discussion) 338-340.

Electrode properties of highly pure commercial iron, sample of stainless steel, and of electrothermally prepared chromium were compared; stainless steel or stainless iron appears to be specially suitable as an electrode for controlled electrolytic reduction or oxidation of certain substances.

STEEL CASTINGS

The Superintendent's Point of View, J. R. Bausch. *Steel Founder*, vol. 1, no. 9, Nov. 1930.

Relation between selling of steel casting and quality production; need of rigid inspection method.

CREEP. Creep Limit of Cast Steel at Elevated Temperatures. *Foundry Trade Jl. (Lond.)*, vol. 43, no. 743, Nov. 13, 1930, pages 335-336, 6 figs.

Review of various methods and results of creep test with particular regard to work of A. Pomp, A. Dahmen, A. Thum and H. Holdt; experiments with constant load and constant temperature; creep limit can be determined with sufficient degree of accuracy by examining rate of elongation; effect of microstructure upon creep limit.

ALLOY. Trends in Cast Alloy Steel, A. W. Lorenz and D. C. Zuege. *Product Eng.*, vol. 1, no. 12, Dec. 1930, pages 560-561.

Present status of alloy steel castings briefly summarized.

Chromium Cast Steels Resist Heat and Corrosion, H. D. Phillips. *Foundry*, vol. 59, no. 1, Jan. 1, 1931, pages 65-69, 6 figs.

Uniform Hardness Obtained by The Aerocase Process . . .

A thin bar of S.A.E. 1020 steel, 15 inches long, resting on the bottom of this 12 in. by 18 in. pot, remained vertically in the Aerocase bath for 30 min. at 1600° F. and then was removed and quenched in water. Upon examination of 2 inch sections of the bar, *each showed the same case depth and the same carbon concentration*. Although this case-depth *uniformity* is most unusual for a liquid bath, it is typical of the results possible with the Aerocase Process on other steels and at other hardening temperatures. The Aerocase Process will simplify your hardening . . . let us discuss it with you.

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2. *Uniform Heating*... The bath is uniformly heated throughout, thereby eliminating any localized over-heating. All the heat is generated in the charge itself, and no part of the furnace is hotter than the charge.

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5. *Excellent Mixing of Bath*... Stirring of the bath is an inherent feature, steels containing heavy alloying elements are made without segregation. Gases and solid non-metallic inclusions are rapidly eliminated.

6. *Remelts Alloy Scrap Without Loss of Alloys*... Scrap containing valuable alloys are re-melted into good ingots without loss of alloys. Stainless steel scrap is re-melted without loss of chromium or nickel, and with no carbon increase.

7. *Comfortable Working Conditions*... No part of the outside of the furnace is uncomfortable to touch with the bare hand. No heat radiates from the sides of the furnace. It is clean and cool at all times.

8. *Flexibility*... Composition of melt may be changed as often as desired. Linings are easily installed. Shut-downs and delays are not costly.

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(Cont. from page 80) is provided by coating the concrete when dry with asphalt or sodium silicate before putting in the lining. A very substantial tank can be made by pouring a concrete shell, lining it with lead and then putting an additional lining of acidproof brick.

Sometimes it is advisable to make a tank according to the drawings on page 80. Its special features are a reinforced concrete wall, lined with two rows of acid-resisting brick, bonded together by an acidproof cement. Large tanks of this type are often 18 in. thick (9 in. of reinforced concrete and 9 in. of acidproof brick). It is advisable to provide a 1-in. cushion of plastic cement between the brick and concrete to take care of the difference in expansion and contraction of the two materials with temperature changes.

Sulphur for Bonding Agent

Another type of concrete tank is made along similar lines, with acid-resisting brick bonded together with melted sulphur. Since sulphur is very inert chemically, acid has very little effect on it. However, it is not easy to make. Sulphur when heated becomes rather thin and if it is heated still more it gets almost like molasses, so the bricks must be laid at just the proper temperature. If they are not, a poor job is bound to be the result. Sulphur cement is also inclined to be brittle and crack.

Asphalt and tar waterproofing are sometimes used but are not effective since acid softens tars of low melting point while those of high melting point are brittle.

A poor job of bricklaying will undoubtedly be quite expensive. It is quite obvious that if the acid seeps behind the brick it will immediately attack the concrete foundation or walls and will put the surface of the concrete in such a condition that an acid-resisting cement or other type of bonding material will not stick to it. This, of course, means that the brick will have to be torn out over a large area, the concrete chipped out and rebuilt. If the tanks have several weak spots in them, spots which do not leak when the tank is first made but under the repeated expansion and contraction (which the tanks must undergo due to the variations in operating temperature), these weak spots will sooner or later make themselves known and the acid will be able to start its destructive action on the concrete. It may be said at this time that a concrete tank properly built is one of the best pickling tanks that can be made, but it must also be said that there is considerable gamble attached, and it has been this uncertainty that has kept them from being more widely adopted.

Old Time Tanks of Granite

The oldest pickling tanks were made of stone or slate. However, they are seldom seen now because of the difficulty of obtaining good acid-resisting stone, particularly in the large slabs required. Tanks of New England granite have been known to last as long as 35 years. Granite is a high-silica rock not attacked by sulphuric acid.

It is always advisable, except when a concrete tank is being used, to dig a pit in the floor sloping toward the sewer. The pit should have stringers 8 in. or wider, the tops of which are level, to support the tanks. Drainage is essential, since it is almost impossible to prevent any liquid from ever overflowing, or leaking. Such construction allows the working floor to be clean and dry, and also holds the tanks themselves out of any spilled pickling liquors, which, by the evaporation of water, would tend to attack the outside of tank, the bolts, nuts, and threaded parts of the rods which hold the tank together. In many localities the disposal of spent liquor is a serious problem.

Helpful Literature For the Asking

Metallurscope—E. Leitz, Inc. This instrument serves for microscopical examination of metal specimens in laboratories and work shops. It is of portable construction and can easily be transferred from one plant to another. Bulletin G-3.

Heat Treating Furnaces—W. S. Rockwell Co. Catalog on Rockwell continuous heat treating furnaces, pusher type, electric or fuel. These are adapted to heat-treating, hardening and tempering, carburizing, etc. Bulletin G-1.

Automatic Control Instruments—Brown Instrument Co. Folder showing application of pyrometers and automatic control instruments to the regulation of temperature in thirty makes of metal heat treatment furnaces. Bulletin G-2.

Quenching Media—E. F. Houghton & Co. A 48-page booklet by the Houghton research staff covering the use of various quenching media and describing how uniformity is made possible with oil hardening. Bulletin G-4.

X-Rays—General Electric X-Ray Corp. "Industrial Application of the X-Ray," a forty-page brochure explaining the value of X-rays in various industrial processes and describes the apparatus required. Fifty selected radiographs are illustrated. Bulletin E-3.

Heat Resisting Alloy—Ohio Steel Foundry Co. 20-page bulletin on Fahrite Heat Resisting Alloy, showing photographs of typical installations of this material. Bulletin No. E-7.

Buyers Guide—International Nickel Co. Buyers Guide to Nickel Alloy Steel Products. A tabulation of sources of supply for the more commonly used forged, rolled, cast or drawn products made from nickel steels and alloys. Ask for bulletin No. E-8.

Alloy Steel Handbook—Republic Steel Corp., has available a revised edition of the Agathon Alloy Steels Handbook. This contains complete instructions for the heat treatment of the various steels in chart form for easy reading. Ask for bulletin No. E-10.

Alloys—Calorizing Co. Heat Enduring, Corrosion Resisting Alloys. A technical bulletin giving physical properties of nickel-chromium iron alloys at all operating temperatures. Photographs of typical applications are included. Ask for bulletin No. E-12.

Gas Heat—American Gas Association. Send for a copy of the new book Gas Heat. No charge. Gas is now the preferred fuel for all industrial purposes. Ask for bulletin No. E-13.

Refractory Cements—Botfield Refractories Co., have prepared a 12-page booklet describing high temperature fire brick cements, including chrome cements and mixtures for surfacing and bonding fire brick in all types of furnaces. Bulletin No. E-14.

High Temperature Alloy—Michigan Steel Casting Co. A 16-page bulletin containing illustrated descriptive matter of their alloy castings and fabricated products for use in high temperatures. Ask for bulletin No. E-15.

Ingot Molds—Gathmann Engineering Co. A new book covering the subject of ingot molding. It contains numerous illustrations of the effects of various methods of finishing and casting on the reliability of steel products. Booklet C-1.

Pyrometers—Charles Engelhard, Inc. Bulletin describing features of indicating and recording pyrometers. Treats on such subjects as sensitivity, resistance, support and control of moving coil, and temperature coefficient. Bulletin E-29.

Heat Treating Equipment—Case Hardening Service Co. 24-page catalog of supplies and accessories for heat treating plants. Contains numerous illustrations and many helpful suggestions for economic heat treating and equipment operation. Bulletin No. E-19.

Heat Treating Wall Chart—Chicago Flexible Shaft Co. Chart covering temperature conversion, heat treatments for S.A.E. steels and other data for handy reference in the heat treating department. Bulletin E-28.

Ferro Alloys—Electro Metallurgical Sales Corp., has issued the third edition of "Electromet" Ferro Alloys and Metals which describes fully the products furnished by this Corporation to the various metallurgical industries. Ask for bulletin No. E-22.

Alloys—General Alloys Co., has gotten out a new bulletin on chrome nickel and straight chrome heat and corrosion resisting alloys known as bulletin E-23.

Metal Progress, 7016 Euclid Ave., Cleveland.

Please have sent to me the following literature as describing under "Helpful Literature for the Asking" in March METAL PROGRESS. (Order by number.)

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Helpful Literature Continued.

Automatic Temperature Cutout—Hevi Duty Electric Co. A new leaflet has been published describing the new "Automatic Temperature Cutout," which can be applied to any type of furnace. Ask for bulletin E-24.

Time Cycle Contactors—Automatic Temperature Control Co. Cycle controllers for the regulation of process operation are described in detail in the revised bulletin on timer application. Ask for bulletin No. E-25.

Alloys, Heat-Resisting—Driver-Harris Co. A brochure illustrating interesting Nichrome installations. Nichrome is the original heat-resisting casting. Ask for bulletin D-1.

Ascoloy 55—Allegheny Steel Co. A technical bulletin describing this chromium iron alloy will be sent on request. Ask for bulletin D-5.

Hardness Testers—Wilson-Maeulen Co. Bulletin H-9 describing applications of the Rockwell hardness tester to a variety of types of work in many different industries. Bulletin D-7.

Hy-Ten Steel—Wheelock, Lovejoy and Co. Hy-Ten steels range in carbon from .10 to 1.00 per cent. There is a Hy-Ten grade for every vital machine part. Bulletin D-8.

Fatigue Testing Machine—Thompson Grinder Co. A bulletin describing the rotating beam type fatigue testing machine. Giving interesting data on fatigue testing. Bulletin D-9.

Chromel Resistance Wire—Hoskins Mfg. Co. Catalog and handbook describing Chromel resistance wire and other resistance alloys, also thermocouple alloys, giving technical information and data. Bulletin D-10.

Globar Heating Elements—Globar Corporation. Bulletin "Globar Non-Metallic Electric Heating Elements" which gives the physical characteristics and applications of Globar elements. Bulletin D-12.

Tool Steels—Carpenter Steel Co. Bulletin "Timbre and How It Affects the Properties of Carbon Tool Steel." Defines Timbre and illustrates and describes Timbre testing. Published by the research department. Bulletin C-6.

Deoxidizers—Vanadium Corp. of America. Leaflet describing Alsifer, a material used for the deoxidation of steel during manufacture. Ask for bulletin No. B-6.

Corrosion and Heat Resisting Steels—Colonial Steel Co., Vanadium Alloys Steel Co., and Anchor Drawn Steel Co. Booklet gives complete data regarding stainless A, stainless B, stainless I, stainless FMS, stainless N, stainless U and stainless CNC. It is intended for shop men to whom it gives valuable technical information. Ask for bulletin No. B-4.

Heat Treating Chemicals—Roessler and Hasslacher Chemical Co. Booklet "Case Hardening and Heat Treatment of Steel." Comprehensive data on cyanides for surface hardening, physical properties and methods of use of salt baths for drawing, annealing and general hardening. Ask for bulletin No. B-13.

Fuel Fired Furnaces—Electric Furnace Co. Eight-page bulletin illustrating oil and gas fired continuous and batch type billet heating, forging and car type furnaces for heating, normalizing and heat treating, also labor saving material handling equipment. Ask for bulletin No. B-18.

Nirosta Buyers Guide—Krupp Nirosta Co., Inc. A concise listing of Companies, producing Nirosta metal, their addresses and the forms of material they are prepared to furnish. Ask for bulletin No. B-19.

Furnaces—Strong, Carlisle and Hammond Co. invites your requests for their bulletins and reprints of recent furnace installations. Your inquiries are solicited. Ask for bulletin No. B-20.

Industrial Regulators—Minneapolis-Honeywell Regulator Co. Booklet describing their motorized valves used in furnace temperature regulation. These valves operate with their regulators or with any pyrometric controller to regulate flow of gas, oil and air. Bulletin F-20.

Resistance Thermometers—Leeds and Northrup Co. Revised catalog treating in detail resistance thermometers for recording, controlling and indicating temperatures, covering heating and ventilating, applications in refrigeration and chemical plants, gas-making and other low temperature applications. Bulletin F-19.

Steel Handbook—Jos. T. Ryerson & Sons, Inc. Handbook on Tool and Alloy Steels. Description, technical data and general information on tool and alloy steels. Also nontechnical description of heat treating methods and shop practice applying to various steels. Bulletin F-18.

Induction Furnaces—Ajax Electrothermic Corp. This bulletin gives latest information regarding coreless induction furnaces in capacities up to several tons, and motor-generator equipments for energizing the furnaces. Bulletin F-17.

Scale Prevention—Dearborn Chemical Co. Booklet describing latest scientific methods of treating water for prevention of scale, corrosion and foaming in steam boilers, dealing with related problems in connection with scale and corrosion in other power plant equipment. Bulletin F-16.

Rotary Hearth Furnaces—George J. Hagan Co. Bulletin covering various rotary-hearth type furnaces built and installed by this company. Bulletin includes photographs of typical installations. Bulletin F-13.

Pickling Equipment—Weaver Brothers Co. Bulletin on Weaver-built Monel metal pickling equipment showing baskets and crates designed to meet every pickling need. Bulletin F-14.

Resilia—Bethlehem Steel Company has published a folder describing Resilia, a silicon-manganese spring possessing great strength, lasting resilience, and remarkable fatigue resistance. Bulletin F-12.

Oil Burners—Ryan, Scully & Co. Booklet on low pressure automatic oil burners, completely describing and illustrating this type of burner installation. Booklet F-5.

Furnaces—Surface Combustion Corporation invites your request for the following new bulletins: Cauldron Furnaces and Solution Heaters F-7; Soaking Pits, F-8; and Roller Hearth Annealing Furnaces F-9.

Furnaces—American Electric Furnace Co. has a new bulletin covering carburizing and annealing furnaces in the 36" and 48" widths. A request for bulletin F-6 will bring immediate response.

Heating Machines—American Gas Furnace Co. Bulletin describing and illustrating latest developments in economical heating machines for heat treatment, case hardening, coloring, brazing, etc. Bulletin F-4.

Electric Heating Equipment—Westinghouse Electric & Mfg. Co. 100-page catalog covering industrial heating equipment. Publication includes operating data, charts, tables and installation photographs in addition to specifications and illustrations of industrial heating equipment. Bulletin F-2.

Aluminum Alloy Castings—British Aluminum Co. Ltd. Booklet contains information on aluminum alloys used in all manner of light alloy castings. Contains a quantity of technical information for foundries and users of aluminum alloys and alloy castings. Booklet F-1.

Tool Steel Handbook—Columbia Tool Steel Co. Description and correct use of tool steels. Hints on how to avoid hardening failures. Also, heat treating methods and valuable information tables. Booklet G-7.

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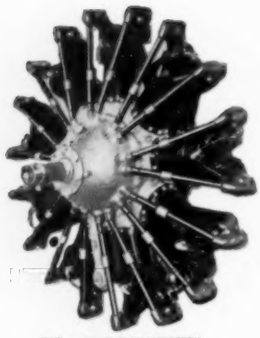

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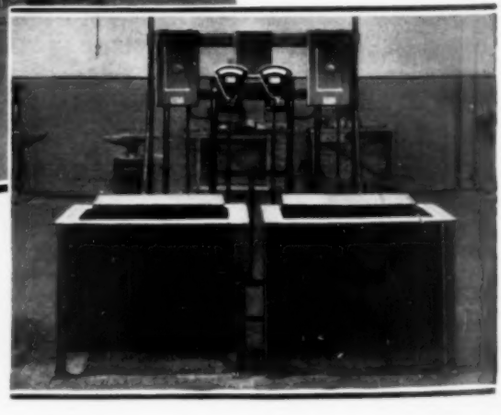
General view, heat treating department, the Pratt & Whitney Aircraft Co., Hartford, Conn., showing G-E electric furnaces, lead pots, etc., equipped with G-E control



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